CLIMATE CHANGE MITIGATION STRATEGIES FOR KENTUCKY

POLICY OPTIONS FOR CONTROLLING GREENHOUSE GAS EMISSIONS THROUGH THE YEAR 2020 AD

by

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June 30, 1998

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EXECUTIVE SUMMARY

Emissions of greenhouse gases (GHGs) in Kentucky are projected to increase significantly unless several policy changes are implemented. A broadly-based technical advisory committee was formed to develop a range of policy options that could reduce GHG emissions without imposing undue economic burdens on Kentucky residents and businesses. Policy options to reduce the emission of GHGs in Kentucky have been designed to meet two criteria:

(1) The policies proposed for consideration must not be too costly. Indeed, wherever possible, they should be designed to generate net benefits for the Commonwealth's economy.

(2) The policies proposed for consideration must be flexible. It should be possible to implement them on a small scale at first, to expand or intensify them over time, and to adapt them as conditions change or as practical experience is gained.

Many of the policies presented in this report are enhancements or intensified versions of existing programs that are now being carried out by public and private sector organizations. Others represent new initiatives. The report presents the policy options first in a relatively modest form that could be implemented without large changes in budgets or investment patterns. Application of these modest proposals would achieve a reduction in the rate of GHG emissions equivalent to 13 million tons of CO_2 per year by 2020. These reductions, when coupled with a baseline reduction for carbon sequestration of 38.2 million tons, give a net emissions figure of 205 million tons per year for 2020. If larger reductions in GHGs are found to be necessary the policies can be maximized or adapted in ways that are described in Chapters 6 and 7. These maximum effort policies would result in reductions in emission rates of up to 52 million tons per year. Subtraction of these reductions along with baseline levels for carbon sequestration from gross 2020 emission projections give a net emissions figure of 167 million tons for 2020. This would be equivalent to the net emissions figure found for the Commonwealth of Kentucky for the year 1990. These results are summarized in the following table:

Sector	Policy Options to Reduce Greenhouse Gas Emissions	Modest Options (tons CO_2 per year)	Max. Effort Options (tons CO_2 per year)
Residential	Enforcement of building codes	231,255	952,022
	Home Energy Rating System (HERS)	66,909	509,378
	Solar heating for low temp. applications	28,984	130,119
	Solar electric systems	11,538	82,085
Commercial	Enforcement of building codes	583,074	2,332,296
	Energy efficiency in government buildings	94,227	456,336
	Solar heating for low temp. applications	21,805	94,227
	Solar electric systems	9,176	58,460
Industrial	Expanded IAC/KPPC programs	113,288	5,531,419
	Solar heating for low temp. applications	77,403	372,214
	Recovery of HFC-23 byproduct	3,131,004	6,258,309
	Coal-bed methane recovery	23,349	200,194
	Landfill gas recovery	720,000	1,440,000
Transportation	Feebates for fuel efficient vehicles	1,244,404	2,392,272
Utilities	Shift coal to gas (NGCC/IGCC/AFT)	3,652,701	10,950,702
Agriculture	Manure management	38,232	141,827
Carbon seq.	Urban forest management programs	272,888	2,728,879
	Rural forest management programs	2,767,905	17,146,098
Totals	Totals reductions due to for policy options	13,188,142	51,776,830
	2020 Baseline corrected for reductions	243,640,613	204,951,918
	2020 Baseline minus base sequestration	205,440,613	166,751,918

Several policy options were found to have significant potential for GHG emissions reduction. These include the following:

- Improvements in forest management and timber production leading to increased rates of carbon sequestration;
- The use of clean coal technologies and natural gas to generate electricity, replacing a number of existing conventional coal power plants;
- Reduction of the emissions of chlorofluorocarbon manufacturing byproducts;
- Improved end-use efficiency in the industrial sector; and
- Improved construction practices and enforcement of energy-related building codes in the commercial and residential sectors.

In addition, a variety of other policies and programs can be combined to yield significant reductions in GHG emissions.

Collectively, the sum of reductions derived from all options, large and small, was found to be sufficient to reduce Kentucky's GHG emissions in 2020 to the 1990 level, if the policies are implemented in a vigorous and sustained manner.

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1. ASSESSING THE IMPACTS OF MITIGATING STRATEGIES

Projections of world climate change due to global warming are characterized by scientific uncertainty.[1] We do know that greenhouse gases (GHGs), carbon dioxide in particular, have been increasing in the atmosphere since the turn of the century, and that the trend continues. Conway *et al.* (1994) have reported a global growth rate for all NOAA/CMDL flask sampling sites of 1.43 ppm per year during 1981-1992. In the same time frame, the CDIAC has reported an annual 1992 mixing ratio[2] for CO_2 of 356.4 ppm at Mauna Loa, Hawaii.[3] Precise, direct measurements of CO_2 levels in the atmosphere are not available for the turn of the century for comparisons sake, but these levels can be inferred from gases trapped in polar ice sheets and snowpack (firn).[4] Estimates from one such source, the Siple Station ice core, give an average atmospheric concentration for CO_2 of 295.3 ppm for the period 1899 - 1903.[5] This gives a 20.7 percent increase since the turn of the century through 1992 and, if the global rate described by Connely *et al.* (1994) is taken as a linear function over the period 1992 to 2000, we predict a level of 367.84 ppm in 2000 AD — an increase of approximately 25 percent over the past 100 years. The increase since the start of the industrial revolution some two hundred years

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[1] Paté-Cornell, Elisabeth, *Uncertainties in Global Climate Change Estimates,* Climatic Change, Volume 33, pp. 145-149 (1996).

[2]Mixing ratios in ppm are derived by dividing the number of moles of carbon dioxide in a sample by the total number of moles present and multiplying by one million, a mole fraction expressed as parts per million. Concentrations in parts per million by volume (ppmv) are derived by dividing the volume of carbon dioxide in a sample by the total sample volume and multiplying by one million. The terms "mixing ratio" in ppm and "concentration" in ppmv are interchangeable for ideal gases.

[3] Conway, T.J., P.P. Tans, and L. S. Waterman; Atmospheric CO_2 records from sites in the NOAA/CMDL air sampling network. In T. A. Boden, D. P. Kaser, R. J. Sepanski, and F. W. Stoss (eds.), *Trends '93: A compendium of Data on Global Change.* ORNL/CDIAC-65. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee, U. S. A. As noted in http://cdiac.esd.ornl.gov/cdiac/trends_htm/trends/co2/noa2/maun-tre.htm April 5, 1997.

[4] Battle, M., *et al., Atmospheric gas concentrations over the past century measured in air from firn at the South Pole,* Nature, Volume 383, pp. 231-235 (1996).

[5] Neftel, A., H. Friedli, E. Moor, H. Lötscher, H. Oeschger, U. Siegenthaler, and B. Stasuffer. Historical CO_2 record from the Siple Station ice core, pp 11-14. In T. A. Boden, D. P. Kaser, R. J. Sepanski, and F. W. Stoss (eds.), *Trends '93: A compendium of Data on Global Change.* ORNL/CDIAC-65. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee, U. S. A.

ago is on the order of 30 percent.[6] Thus, it is clear that most of the increase we see now has occurred in the past one hundred years and climate change due to global warming, if it has occurred as a result of these emissions, should be accounted for accordingly.

Finding direct proof of climate changes for the past 100 years or so that are positively associated with concurrent increases in GHGs is not as simple a thing to do as it may seem. We do know that the Earth's average surface temperature this century may be as warm or warmer than any since 1400 AD, that this temperature has increased by 0.3 to 0.6 °C over the past century, that the last few decades have been the warmest this century, that sea level has risen 10 to 25 cm, and that mountain glaciers are generally in retreat.[7] We may opine all we want that these changes are the direct result of the accumulation of GHGs in the atmosphere, but our ability to conclusively prove this statement at present is somewhat limited. The system in question - the atmosphere of the planet Earth - is thermodynamically open, poorly mixed, never at equilibrium, and given to irreversible changes. This leaves the study of "cause and effect" in the hands of huge statistically driven "world circulation models" — the WCMs of the current climate change literature. The WCMs are improving and some now show a model fit between the known conditions of the atmosphere for this century and observed changes in global temperature patterns. The first generation of WCMs failed to take the cooling effect of sulfate aerosols into account and thus tended to over-estimate atmospheric warming due to GHG accumulation. More recent WCMs take aerosols into account thereby providing model results which, for some areas, match up better than before with documented temperature trends from 1860 to the present.[8] This begs the question: "Can we use the current generation of WCMs to predict the impact of mitigation strategies?" The answer is "yes", but with the qualification that projections for future levels of GHGs in the atmosphere and associated impacts still do not have a true high degree of confidence. At present, and probably for some time into the future, we will have to be content with broad

[6] *Our Changing Planet: The FY 1997 U. S. Global Change Research Program.* A report by the Subcommittee on Global Change Research, Committee on Environment and Natural Resources of the National Science and Technology Council: A supplement to the President's Fiscal Year 1997 Budget, p. 30 (1997).
[7] *Ibid., Our Changing Planet,* p. 34 (1997).
[8] Mitchell, J. F. B. *et al.*, *Climate Response to the Increasing Levels of GHGs and Sulphate Aerosols,* Nature, Volume 376, pp. 501-504 (1995).

ranges. Given this understanding, it is fair to say that without effective mitigating strategies we can expect by 2100 AD to see average surface temperatures increase from 1 to 3.5 °C. This is a warming rate greater than any estimated for the past 10,000 years and, if it indeed occurs, we should anticipate a sea level rise of 15 to 95 cm by that time.[9] It would be mistake to take lightly the implications of these projections.

1.1 Documentation of Global Temperature Rise

One problem that we have with our predictive abilities, and subsequently with our abilities to assess the impacts of mitigating strategies, is that for the past few decades ground-based temperature monitoring systems have shown a steady increase in the Earth's surface temperatures while satellite monitoring systems have shown a steady decrease in lower atmospheric temperatures for the same time period.[10] The record containing this anomaly consist of files merged from a number of satellites, some of which operated for relatively short periods. This finding has been addressed recently by Hurrell and Trenberth (1997)[11] who state at the outset of their paper that "the rate of global annual mean surface warming of 0.13 °C for the period 1979-95 differs substantially from the global lower-tropospheric cooling trend of -0.05°C per decade inferred from the record (MSU-2R) of radiance measurements by the satellite Microwave Sounder Unit."[12] Hurrell and Trenberth developed a detailed study of this problem taking into account known relationships between tropical sea surface temperatures (SST) and temperatures in the lower atmosphere. They used measured SST values to force atmospheric temperatures in a fourth generation NCAR Community Climate Model (CCM3, Version 3.0) and then compared the results to the MSU-2R time sequence satellite record. The model fitting exercise identified two step-function break points in the MSU-2R record in mid-1981 and mid-1992. These break-points can be identified

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[9] *Ibid., Our Changing Planet,* p. 34 (1997).
[10] Monastersky, R.; *Global Temperatures Spark Hot Debate,* Science News, Volume 151, pp. 156 (1997).
[11] Hurrell, J. W., and K. E. Trenberth; Spurious trends in satellite MSU temperatures from merging different satellite records, Nature, Volume 386, pp. 164 (1997).
[12] Hurrell and Trenberth cite the following articles in support of this statement: Christy, J. R., Spencer, R. W. and R. T. McNider, *J. Clim.*, Volume 8, pp. 888-896 (1995); Spencer, R. W., Christy, J. R., and N. C.

with transitions from polar satellites NOAA-6 to NOAA-7 and NOAA-10 to NOAA-12, respectively.   Thus, it does appear from the work of Hurrell and Trenberth that a problem exists with the merged satellite data, although this has not been proven to everyone's satisfaction. Their conclusions given below are worth noting nonetheless:

> Therefore, the cumulative evidence strongly suggests the recent coldness and the overall downward trend in MSU-2R temperatures are spurious and arise from difficulties in matching records between satellites combined with surface emissivity influences. The latter add considerable noise, especially over land, while the merging of satellite records requires long overlaps between different satellites and stable orbits that are not always achievable.[13]

 Hurrell and Trenberth go on to suggest "the real trend in MSU temperatures is likely to be positive, albeit small".

The debate over the validity of the MSU-2R record is quite spirited. Monastersky quotes J. R. Christy of the University of Alabama in Huntsville as suggesting that Hurrell and Trenberth have discovered a real change in the atmosphere, not an error.[14] Christy contends that the step-breaks observed by Hurrell and Trenberth are due to volcanic eruptions and El Niños. "The lesson", says Christy, "is that the tropical atmosphere has a level of complexity that we have not yet grasped." The debate thus continues leaving one with the feeling that nothing has really been resolved, and that in some respects predictions of temperature increases, or the lack thereof, due to GHG emissions must await further work before being fully accepted.

1.2 Uncertainty in Economic Models of Climate Change Estimates

Uncertainties in the extant climate change database lead in turn to uncertainties in the forecasting of economic impacts of weather and climate forcing due to GHG emissions. The economic implications of adaptive strategies selected for the purpose of reducing emissions are similarly difficult to assess. Indeed, according to

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Grody, *J. Clim.,* Volume 3, pp. 1111-1128 (1990); Spencer, R. W. and J. R. Christy, *J. Clim.*, Volume 5, pp. 858-866 (1992).
[13] *Ibid.,* Hurrell, J. W., and K. E. Trenberth , p. 166 (1997).
[14] Ibid., Monastersky, R.; p. 156 (1997).

Schimmelpfennig[15], uncertainty has been handled in the economic analysis of climate change literature "in a cursory manner, if at all." Difficulties in assessing uncertainties arise from a number of factors. Let us assume, for example, we decide to stabilize GHG emissions from the Commonwealth of Kentucky at 1990 levels. The level of reduction needed in 2020 AD to achieve this will itself be a random variable having a probability distribution and a variance, as is the initial estimate of 1990 emissions upon which it is based. We then must consider that we have a large number of ways to achieve the desired reduction, and that each of these choices have probability density functions defining the distributions of each in terms of a mean and variance for the outcome of a particular choice. Efforts to estimate economic outcomes of a particular strategy are further complicated by the vagaries of weather. Rainfall, wind, and temperature extremes are all random variables. Lastly, we must conclude that the degree of radiance forcing for a given choice of emission loadings is also a random variable dependent upon a myriad of factors.

Schimmelpfennig suggests Monte Carlo techniques as one way to deal sensibly with this problem.[16] In the Monte Carlo method, model inputs for each prime variable are drawn randomly from user defined distributions. Thus, no two Monte Carlo model runs can be expected to have the same input or to give the same result. This results in a complex non-linear stochastic system requiring numerous model runs to determine the range of possible outcomes.[17] The benefit of a Monte Carlo approach is apparent. It does indeed take randomness into account and as a result provides the researcher, and those having to make policy decisions, with a glimpse of reality. Unfortunately, at present we do not have all of the statistical distribution data needed to fully develop such an analysis.

Scientific uncertainties, and uncertainties in the world of economic forecasting, naturally lead to a somewhat hazy public perception of global warming. Berk and Schulman recently conducted a study of this issue using factorial survey methods applied

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[15] Schimmelpfennig, David, *Uncertainty in Economic Models of Climate-Change Impacts,* Climatic Change, Volume 33, pp. 213-234 (1996). See page 213.

[16] *Ibid.,* Schimmelpfennig, p. 228 (1996).

[17] Vincent C. Rideout, *Modeling Studies of Socio-Economic-Resource Systems,* in Resources and Development edited by Peter Dorner and M. A. El-Shafie, The University of Wisconsin Press, IBSN 0-299-08250-4, p. 432 (1980).

to over 600 residents of southern California.[18] They conclude that the public, including
the segment lacking a science background, does have the capacity to understand complex
scientific issues. Indeed, they suggest that "efforts to 'educate' the public through sound
bites and other baby talk may do more harm than good." They suspect, however, that the
general public does not yet appreciate the significance of what seems at present to be
arcane scientific debate over minor shifts in climate. As a result, it appears that truly
large local impacts on climate will have to be registered before a resident populace can be
expected to show willingness to pay the costs of mitigation. This situation makes it
challenging for policy makers to develop policy choices.

1.3 The Adaptive Strategies Approach to Mitigating Emissions

Nordhaus[19] was among the first to apply econometric modeling techniques in an
effort to resolve questions of costs to benefit ratios in achieving GHG emission controls.
He developed the dynamic integrated climate-economy (DICE) model which
"incorporates the dynamics of emissions and economic impacts as well as the economic
costs of policies to curb emissions."[20] The problem addressed at the time was simple to
state; namely, that the call for stringent controls and treaty negotiations following the Rio
Earth Summit held in June of 1992 were "progressing more or less independently of
economic studies of the costs and benefits of measures to slow greenhouse warming."
Nordhaus undertook the task of improving on this situation. He concluded, with
extensive qualifications, that a "modest carbon tax would be an efficient approach to slow
global warming, whereas rigid emissions limits or climate stabilization approaches would
impose significant net economic costs." The DICE model upon which these suggestions
were based is a dynamic optimization model for estimating the optimum path for
reductions. Optimization models, as defined by Nordhaus, are often used in economics.
They rely on the correspondence between optimization and the behavior of competitive
markets. Economic-natural parameter models that assist policy makers in selecting "best

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[18] Berk, R. A. and D. Schulman, *Public Perceptions of Global Warming,* Climatic Change, Volume 29, pp.
1-33 (1995). See pages 30-33.
[19] Nordhaus, W. D., *An Optimal Transition Path for Controlling GHGs,* Science, Volume 258, pp. 1315-
1319 (1992).

estimate" predictions of the future have since evolved on a parallel path. These models treat uncertainty by providing "best estimates" as probability distributions with known mean and variance. Optimum policies are then found as functions of these distributions.[21]

Climate change mitigation strategies are unique in many respects among studies and programs having the purpose of defining policy options. The time frame over which these policies will operate are long by most standards, extending out for decades if not centuries. This, of course, contributes even more uncertainty to numeric results derived from model estimates. However, as noted by the IPCC Working Group III, this long time horizon also provides some tangible benefits, for example —"time for the accumulation of incremental improvements in abatement techniques or for the emergence of revolutionary, environmentally benign technologies."[22] Considerations such as these make the work of Lempert, *et al*. especially interesting. These authors suggest a different solution to the problem of having to deal with large uncertainties in evaluating mitigating strategies. They suggest an adaptive approach, or strategy, — "one that can make midcourse corrections based on observations of the climate and economic systems".[23] In other words, and as described by the authors, a simple adaptive strategy designed to be robust across many possible futures. The advantage of this approach to developing mitigation strategies is self-evident given the unlimited number of GHG-driven outcomes possible over the long time horizons involved. 'Do-a Little' and emission stabilization policies based on fixed 'best estimates' of the future are irrevocable trajectories cast in stone. Adaptive strategies, on the other hand, are fluid and amenable to change along the way.

[20] *Ibid.,* Nordhaus , pp. 1315 (1992).
[21] Lempert, R. J., Schlesinger, M. E. and S. C. Bankes*., When We Don't Know the Costs or the Benefits: Adaptive Strategies for Abating Climate Change*, Climatic Change, Volume 33, pp. 235-274 (1996). See page 236.
[22] Arrow, K. J., Parikh, J and G. Pillet, *Decision-Making Frameworks for Addressing Climate Change,* in Climate Change 1995: Economic and Social Dimensions of Climate Change published for the Intergovernmental Panel on Climate Change by Cambridge University Press, p. 60 (1996).
[23] *Ibid.,* Lempert, R. J. *et al.,* (1996).

2. ENVIRONMENTAL POLICY AND ELECTRIC UTILITY RESTRUCTURING

The past quarter century of American history has been characterized by sweeping changes in environmental policies and legislation, and in the restructuring and deregulation of much of the nation's industrial, utility and transportation sectors. Transportation and electric utility industries have been the focus of much of these activities by virtue of their utilization of fossil fuels. Fossil fuel combustion has long been recognized as a principal source of acid rain, urban smog and greenhouse gas emissions, carbon dioxide in particular. The restructuring of the utility industry, the major contributor of greenhouse gas emissions for the Commonwealth of Kentucky, is expected to affect the level of these emissions in both the immediate and far distant future. An understanding of the timing, direction and magnitude of these changes is critical to the development of mitigation strategies for Kentucky and for the development of a baseline scenario for the State as well.

2.1 Principal Components of Federal Environmental Legislation of the 1970s

Three pieces of Federal environmental legislation passed into law in the early 1970s have shaped much of the Nation's environmental policies since that time. These were, in the order of becoming law, the National Environmental Policy Act (NEPA) of January 1, 1970[24]; The Clean Air Act of 1970[25]; and the 1972 Federal Water Pollution Control Act[26]. In addition, a number of Federal agencies with focus on environmental issues and human health were combined into the Environmental Protection Agency (EPA) through an executive reorganization plan sent by President Nixon to Congress on July 9, 1970. EPA was formed as an independent agency of the Executive Branch on December 2, 1970. The Energy Research and Development Administration (ERDA), the

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[24] 42 U.S.C.A. ¶ 4321 et. seq., 83 Stat. 852, Pub. L. 91-190.
[25] Pub. L. 91-604, 84 Stat. 1676, 42 U.S.C. ¶ 1857 et. seq. (1970).
[26] Act of October 8, 1972, Pub. L. 92-500, 86 Stat. 816 (codified at 33 U.S.C. ¶¶ 1251 et. seq. [Supp. 1973], amendment 33 U.S.C. ¶¶ 1151 et. seq. 1970.

precursor of our present Department of Energy (DOE), was established during the same period through the Energy Reorganization Act of 1974.[27]

The two overriding issues that brought these legislative Acts and agencies into being were a growing awareness on the part of the American public of serious and continuing environmental degradation, and the oil embargo of 1973. The oil embargo spawned an additional set of legislative acts and Presidential directives which, while not focused specifically on environmental issues, proved no less important to these causes. The Energy Supply and Environmental Coordination Act of 1974, for example, was passed with intent of encouraging use of domestic coal which then and now was one of the most abundant sources of domestic energy supply.[28] President Carter's national energy plan submitted to Congress in April 1977 was also designed to encourage development of domestic energy resources with particular emphasis on coal.[29] President Carter also emphasized the maintenance of air quality as an integral part of his plan. Indeed, the need to find ways of using coal as an energy source without furthering the degradation of the nation's air resources has, from the beginning of this period to the very present, been one of the more challenging issues facing the country. The resolution of this issue is obviously critical to economic development in the Commonwealth of Kentucky and to the development of greenhouse gas mitigation strategies for the State.

2.2 Early Considerations Of Energy Sector Greenhouse Gas Emissions

Congress revised the Clean Air Act in 1977 (CAA) with the following declaration of purpose of the Act:

> (1) to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population;
> (2) to initiate and accelerate a national research and development program to achieve the prevention and control of air pollution;
> (3) to provide technical and financial assistance to State and local governments in connection with the development and execution of their air pollution prevention and control programs; and

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[27] 42 U.S.C.A. ¶ 5801 et. seq.
[28] Pub. L. 93-319.
[29] *To Breathe Clean Air*, Report of the National Commission of Air Quality, Washington, DC, March 1981, p. 283.

(4) to encourage and assist the development and operation of regional air pollution control programs.[30]

In addition, and through the CAA, Congress established the National Commission on Air Quality (NCAQ) to make a complete and thorough analysis of air pollution control strategies suitable to achieving the goals of the Act.[31] The NCAQ published a major report in March, 1981 in response to a list of seven questions posed to the Commission by Congress. One of these is of particular interest to the Kentucky GHG mitigation study, namely; "Which air pollutants not presently regulated may pose a future threat to health or welfare?" The principal criteria air pollutants proposed in the 1970s for regulation at the time were: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter and sulfur dioxide. All of the criteria pollutants are either directly or indirectly associated with fossil fuel combustion. The utility industry, industrial sources, and private car owners have been the focus of regulatory activities aimed at the control of these air pollutants. Carbon dioxide, however, now a major focus in the 1990s over concerns related to global climate change, was left out of the criteria pollutants list under the CAA.

The NCAQ provided the following summary concerning carbon dioxide in its March, 1981 report:[32]

> Increased carbon dioxide in the atmosphere, resulting primarily from the combustion of fossil fuels, has the potential for causing significant changes to global climate sometime in the next century. Changes to global climate could include changes in temperature, cloud, precipitation, wind patterns, resulting in changes in the distribution of arable land and in the distribution, composition, and productivity of natural ecosystems. Carbon dioxide can remain in the atmosphere for several hundred years; consequently, most current emissions of carbon dioxide can remain in the atmosphere through the 21st century.

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[30] *Selected Environmental Law Statutes,* West Publishing Company, 1983, p. 37. See Pub. L. 95-95, August 7, 1977.

[31] *To Breathe Clean Air*, Report of the National Commission of Air Quality, Washington, DC, March 1981, p. vii.

[32] *To Breathe Clean Air*, Report of the National Commission of Air Quality, Washington, DC, March 1981, p. 50.

We are now at a time in our history where the potential impacts of increased carbon dioxide levels in the atmosphere cited by the NCAQ in 1981, while still not completely proven as accepted fact in their entirety, need to be addressed, and quite possibly in the immediate future. The restructuring of the electric utility industry, and associated environmental policies, are clearly current issues of major importance for this effort.

2.3 Electric Utility Restructuring and Nitrogen Oxide Emissions

There are three gaseous oxides of nitrogen:

NO   --- nitric oxide,

NO_2 --- nitrogen dioxide and,

N_2O --- nitrous oxide.

All are formed as combustion products. The first two in combination ($NO + NO_2$) are generally referred to as NO_X. Nitric oxide comprises the majority of this pair as formed in a combustion process and may make up as much as 95 percent the total NO_X emitted as a stack gas.[33]

NO_2 dissociates into NO and O in the presence of sunlight. The free oxygen molecule formed as a result in turn reacts with O_2 to form ozone (O_3). Ozone will react with residual NO to reform NO_2 and O_2 under ordinary circumstances. In the presence of VOCs (volatile organic hydrocarbons), however, residual NO is scavenged from the atmosphere by organic free radicals. This results in a buildup of ozone in the lower atmosphere, especially over cities and urban areas (smog).

The distribution of ozone precursor emissions among sources is shown in Table 1 below.[34] The potential for long range transport of these gases and their reaction end product, ozone, from areas where production is concentrated (the Ohio River corridor) to the northeast has been the source of much controversy over the past decade. Congress, in an attempt to resolve the issues involved and develop legislation if necessary, established

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[33] *Perry's Handbook of Chemical Engineering,* Seventh Edition, McGraw-Hill, 1997, p.27-27.
[34] The data in Table 1 may be found in any of a number of national publications. See http://ttnwww.rtpnc.epa.gov/naaqsfin/ for more information concerning ozone-haze data and associated national regulations.

eleven northeastern states as an Ozone Transport Region (OTR) and at the same established an Ozone Transport Commission (OTC) to manage affairs in the OTR. The OTC consist of twelve state governors or their designees, and a representative of Washington, DC. Washington, DC and part of Virginia are also included in the OTR.

Table 1. Distribution of Man Made Ozone Precursors

Source	Nitrogen Oxides (NO_x)	Volatile Organics (VOCs)
Utilities	33.0 %	0.2%
Industrial	17.3%	56.9%
Transportation	45.0%	36.9%
Other	4.7%	6.0%

The Environmental Council of States and US EPA, in a separate action, formed an Ozone Transport Assessment Group (OTAG) consisting of representatives from environmental agencies from the thirty-seven eastern most states. Collectively, these groups have conducted extensive studies and modeling efforts to ascertain the truth of the transport issue. At present much uncertainty remains. One point of view, that expressed largely by supporters of controls imposed to curtail NO_X, holds that ozone precursors and ozone are indeed transported over great distance from the midwest to the northeast. The other contends that ozone and precursor impacts are limited to areas within a few hundred miles of the primary source. It is probable, given the vagaries of the weather, that both positions are at times absolutely correct.

Regardless of the position held, it is the expressed view of US EPA that reductions in NO_X will be necessary. Rules currently being debated are to become final in September of 1998, and are to be met by 2002. At present these rules call for the reductions in NO_X emissions shown in the table below.

Table 2. Proposed NOx Reductions to be Achieved by 2002

State	Range in Percent Reduction
New York, Washington DC	10-19%
Virginia, Connecticut, New Jersey, Rhode Island, Delaware	20-29%
Maryland, Pennsylvania, Massachusetts, Michigan, Wisconsin, Illinois, Tennessee, North Carolina, South Carolina, Georgia, Alabama	30-39%
Indiana, Ohio, West Virginia, **Kentucky**, Missouri	40-44%

NO_X emissions can be reduced through control of mixing, combustion and heat transfer processes. None of these processes, however, result in a reduction of carbon dioxide emissions unless they involve a shift from solid fuels (principally coal) to natural gas, or to a coal to gas conversion system in combination with gas turbine electricity generation.

As in the case of long range transport, the question of how restructuring will affect NO_X emission rates is hotly debated. Current runs of EPA's Integrated Planning Model (IPM) and EIA/DOE's National Economic Modeling System, however, now show some agreement with lower NO_X emission increases being projected than previously reported. These models predict rapid increases in NO_X emissions until the decade 2000-2010, after which emissions level off.[35] It is clear, regardless of how this all turns out, that the impacts on Kentucky of the new NO_X reduction requirements will be

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[35]White, Jeffery P., *Electric Utility Restructuring and Environmental Policy,* Edison Electric Institute, September 12, 1997, p. ES-1.

extraordinary, and these impacts will have a profound influence on greenhouse gas mitigation strategies as well.

2.4 Electric Utility Restructuring and Carbon Dioxide Emissions

The electric utility industry has long been identified as a major source of carbon dioxide with the 50 largest utilities in the eastern most states contributing 64 percent of the national electric utility emissions.[36] The burning issue concerning restructuring for these utilities, including those in the Commonwealth of Kentucky, is how each will adjust to the more competitive markets for the sale of electricity once the "monopoly based" market systems are gone. These systems were partially removed at the wholesale level by the Energy Policy Act of 1992 and FERC order 888, which collectively "require utilities to provide nondiscriminatory transmission service for all wholesale transactions."[37] The tendency, given the coming of open retail competition between the utilities, will be to lower the costs of the product (electricity) where possible. This in turn could lead to continued use of older coal-fired plants in lieu of building new generating facilities with current (and expensive) air pollution control devices, and to the continued direct use of coal as an energy source. The outcome of the debate over these possibilities will no doubt have a profound effect on air pollution and, subsequently, on a number of issues relating to utility rates, fuel choices and emission controls.

Older generating units did not for a time have to meet the stringent requirements placed on newer systems through the CAA and thus, if allowed to continue to operate as such, would in effect be allowed an "environmental economic subsidy, providing an incentive to extend the 'lives' of these units."[38] New units built on older station locations do of course meet new performances standards. Acid rain elimination provisions of the 1990 CAA also went into effect on January 1, 1995. These new provisions specifically

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[36] *Benchmarking Air Emissions of Electric Utility Generators in the Eastern United States;* from the Natural Resources Defense Council (NRDC), Public Service Electric and Gas Company (PSE&G), and the Mid-Atlantic Energy Project of the Center for Environmental Legal Studies, Pace University School of Law, (1995), p. 5. This report is available from the internet at: http//www.nrdc.org/nrdcpro.
[37] Ibid, *Benchmarking Air Emissions of Electric Utility Generators in the Eastern United States,* (1995) p. 36.
[38] Ibid, *Benchmarking Air Emissions of Electric Utility Generators in the Eastern United States,* (1995) p. 37.

limit the sulfur dioxide emissions from older plants. Thus, incentives to keep older units operating beyond their typical life span, a process once common-place in the industry, are beginning to be taken away. The question of fuel switching is significantly influenced by these considerations.

This situation and its immediate implications is best summarized in a quote from a recent Natural Resources Defense Council Report (NRDC):[39]

> It is important to note that if competition leads to increased use of higher-emitting coal units in the Midwest and Southeast, the additional emissions will exacerbate pollution problems in downwind areas, such as the Northeast, regardless of where the customers buying the additional power are located. Unless these emissions are controlled, environmental regulators in downwind areas and states will need to impose additional controls on their own citizens and businesses to offset the impacts from these increased emissions.

If one thing about this is clear, it is that the policy issues raised by restructuring are extremely complex, and that questions pertaining to carbon dioxide emissions, questions with at least the potential for becoming the dominant issues for the future, have only just begun to be debated.

The NRDC report goes on to make an observation which is worth noting; namely, that coal-fired units built in the 1950s, 1960s and 1970s still account for three-fourths of the 1995 steam electric generation. Future modifications made at these plants, particularly those operating in the Commonwealth of Kentucky is, of course, of considerable interest to those trying to develop greenhouse gas mitigation strategies for the State.

2.5 Projections for the Future taking Restructuring into Account

We now have the benefit of an extensive and entirely recent literature dealing with the implications of restructuring. Understandably, much of the information is in conflict. This literature has been reviewed by White[40] who chose to place the topics covered under three main headings: Macroeconomics Studies, Focused Modeling

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[39] Ibid, *Benchmarking Air Emissions of Electric Utility Generators in the Eastern United States,* (1995) p. 37.

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Analysis, and Qualitative Issue Discussions. Much of the current interest in restructuring has been focused on issues pertaining to economics, nitrogen oxide emissions and transport and, to a lesser extent, on carbon emissions. The nitrogen oxide emissions are interrelated with ozone levels across the eastern states, especially in the northeast, and these emission rates, and questions concerning long-range transport, projected with and without changes coming from restructuring, are now a source of considerable debate.

The Energy Policy Act of 1992 directs the Energy Information Administration (EIA) to collate and publish an inventory of national emissions of greenhouse gases covering a 1987 to 1990 baseline period, and to provide annual updates. This requirement complements the 1990 amendments to the CAA which in turn requires reporting of carbon dioxide emissions by utilities.[41] The EIA does conduct and regularly publish an analysis of carbon emissions, energy use and the Climate Change Action Plan. At present, the EIA projects a 1.4 percent per year growth rate for electricity sales through 2010, and subsequent increases in carbon emissions. The EIA projections for carbon emissions based on this growth figure are given below.[42]

Table 3. Energy Information Administration Projections of Future Carbon Emissions

Year	Carbon Emissions	Percentage

[40]White, Jeffery P., *Electric Utility Restructuring and Environmental Policy,* Edison Electric Institute, September 12, 1997.

[41] White, Jeffery P., *Electric Utility Restructuring and Environmental Policy,* Edison Electric Institute, September 12, 1997. See page 42, ref. 16.

[42] White, Jeffery P., *Electric Utility Restructuring and Environmental Policy,* Edison Electric Institute, September 12, 1997, p. 8.

millions tons per year		
1994	496	base year
2000	521	5.0
2005	570	14.9
2010	610	23.0
2015	657	32.5

The following conclusions based on these data and on the forgoing analysis can be drawn with reference to utility restructuring.

(1)	It is fair to say that the construction in Kentucky of new coal-fired plants based on past design parameters over the next twenty-five years is very unlikely. Such plants would have to be built with stringent controls for heavy metals, sulfur dioxide, nitrogen oxides, carbon monoxide, particulates and, quite possibly, for carbon dioxide. These types of systems would not enable the power to be competitive in the distant and heavily populated markets of the northeast, and the demand for electricity locally cannot be expected to justify the expense.

(2)	Older generating systems will continue to operate here as long as possible, and an increase in the transmission of electricity from these plants to markets beyond Kentucky's borders should be anticipated.

(3)	New peaking units built in Kentucky over the next twenty-five years will be fired entirely by natural gas.

(4)	Some fuel switching will take place in Kentucky with coal being replaced by natural gas. The degree to which this will take place, however, cannot be predicted with any accuracy at present.

(5)	Emphasis in the State will be shifted to development of coal as a clean energy source, with intense research efforts being made to find ways to shift utility base loads to coal-gas conversion systems that make extensive use of waste heat.

2.6 Response of the Commonwealth of Kentucky to Electricity Restructuring

The General Assembly of the Commonwealth of Kentucky, through House Joint Resolution No. 95 dated March 12, 1998, has established an Electricity Restructuring Task Force, "whose membership shall carefully study the issue of electric restructuring in Kentucky during the 1998-2000 interim and analyze its impacts upon the Commonwealth." The task force is to meet monthly beginning no later than October 1, 1998, and is to report back to the Legislative Research Commission and the Governor with findings and recommendations by no later than November 15, 1999.

3. POPULATION AND GHG PROJECTIONS FOR KENTUCKY

Population projections for Kentucky for 1990 to 2020 have been developed by Sawyer and Scobee for the University of Louisville, Kentucky State Data Center[43]; and by Campbell for the U. S. Bureau of the Census.[44] The projections take a number of factors into account. Migration is projected according to 1990-1994 trends, and it assumed that longevity increases in the future. In general, the assumption of minimal gains from migration confers moderate growth. The opposite assumption provides a high growth scenario.

 The most recent projections from the U. S. Bureau of the Census show a growth rate in Kentucky population six percent below the high growth series of Sawyer and Scobee, but in excess of the projections for moderate growth. The population increases for these projections are as follows:

    (1)   for high growth scenario   = 844,000 persons or 23 percent;

    (2)   increase according to census bureau = 626,000 persons or 17 percent;

    (3)   for moderate growth scenario   = 240,000 persons or 7 percent.

 This gives a 3.5 fold difference between the lowest and highest figure which, as will be shown below, contributes to an even more dramatic difference in GHG emissions. In all three cases, however, population increases at relatively steady rates.

The distribution of population by county for average growth between the moderate and high growth scenarios of Sawyer and Scobee is shown in Figure 1. These projections normalized to the 1990 base year population are shown in Figure 2. Major roads are also indicated in these diagrams.

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[43] Price, M., Sawyer, T. and M. Scobee, *How Many Kentuckians: Population Forecasts 1990-2020. 1992 Edition,* Kentucky State Data Center, University of Louisville. P. 1-7 (1992).
[44] Campbell, P. R., *Population Projections for States, by Age, Race, and Sex: 1993 to 2020,* U. S. Bureau of the Census, Current Population Reports, P25-111, U. S. Government Printing Office, Washington, DC, (1994); as cited in Price *et al.,* (1992).

Figure 1. 2020 Projected Population Distribution for Average Growth Rates

A high growth scenario for Kentucky's population developed by the University of Louisville, Kentucky State Data Center offers a 23 percent increase by 2020. A more moderate growth scenario suggested by the same group suggests 7 percent. The Bureau of the Census, by comparison, offers 17 percent as a growth potential for the Commonwealth. The following figure plots the average value, county by county, taken between the two University of Louisville estimates. For the state as a whole, this average produces a 15 percent increase in total population, a figure used extensively in calculations that follow.

It is evident from this figure that growth patterns leading to increased population densities along the major highway corridors is anticipated.
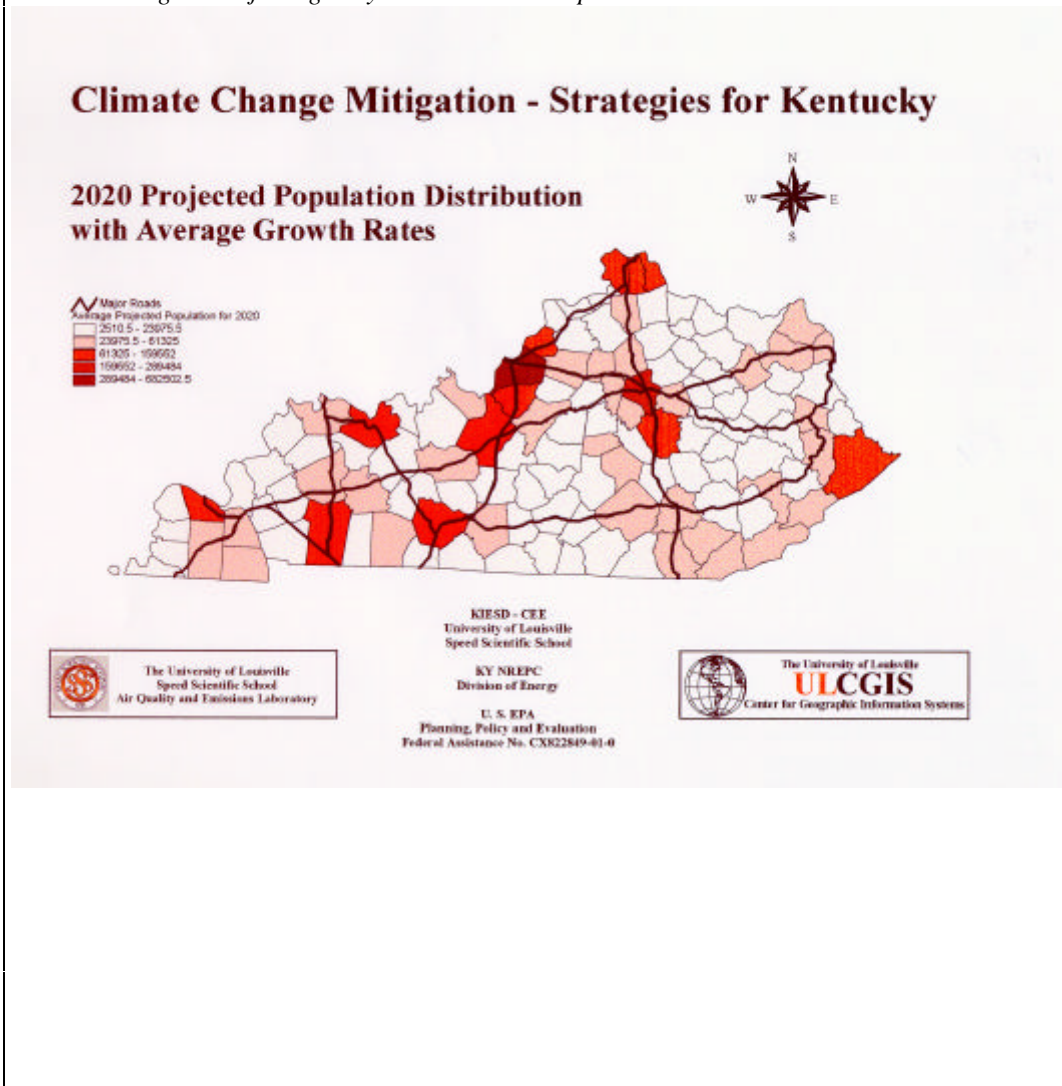
Figure 2. 2020 Projected Population Distribution Normalized to the 1990

Base Year

County populations projected for 2020 normalized to 1990 are presented in Figure 2. These data are presented in a dichromatic format with shading to the reds for counties anticipated to grow, and to the blue for those expected to decrease in population. Here again, the impact of major highway corridors is evident.
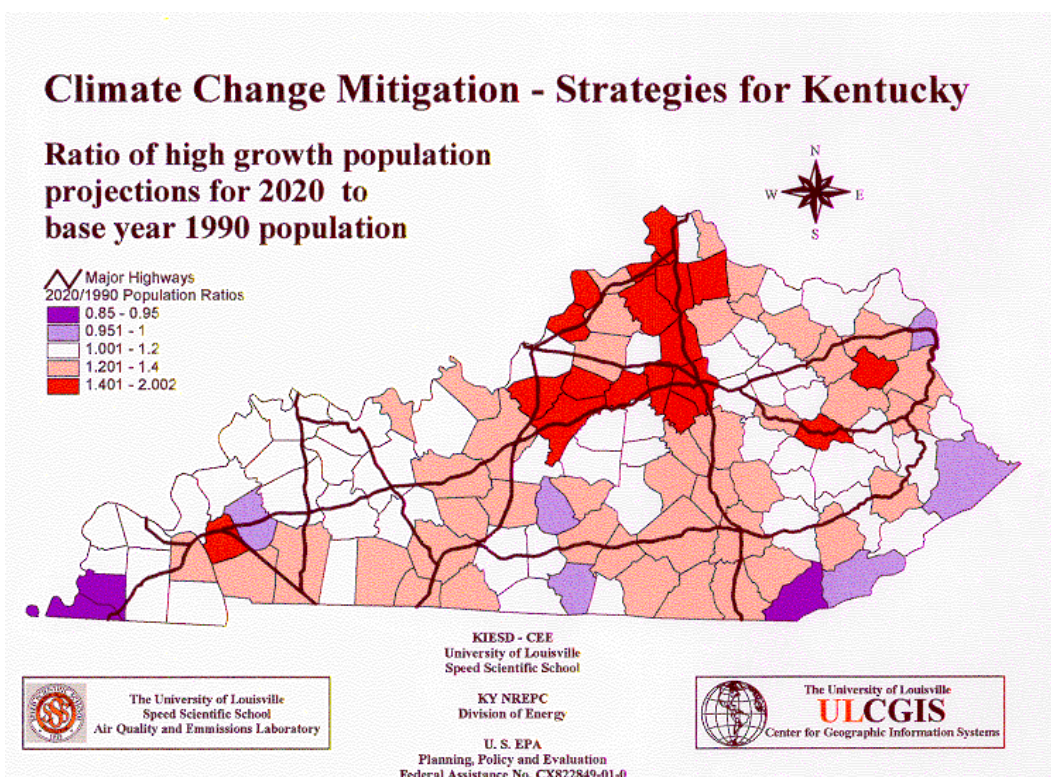
3.1 Population Distributions and Growth Patterns

It is evident from the data given in Figures 1 and 2 that growth in population is expected to occur through 2020 AD primarily along the interstate highway corridors, and along the Commonwealth's parkways. Counties in the eastern portion of the state not directly served by a major highway are expected to lose population. Counties intersected by major highways in the more populous and industrialized parts of the state, on the other hand, are expected to develop even further. Several exceptions to this pattern are notable, in particular Jefferson County. Jefferson's population in 1990 was 665,123. The high growth projection for 2020 AD is 732,026, an increase of 10 percent as compared to the 23 percent high growth increase for the state as a whole. The search for convenience and employment is the probable driving force for the modest changes in Jefferson County, and for the decreases observed in another nine counties. New industry and development are more likely to develop along major corridors of transportation than anywhere else. Our population projections, as one might expect, reflect this phenomena in terms of gain for counties where development is expected, and losses where it is not.

3.2 Baseline Projections of GHG Emissions through 2020 AD

Greenhouse gas emissions, especially those generated by the residential, commercial, and industrial sectors, are driven by population change, by change in gross domestic product, and by technological advances. Utility-generated emissions are also strongly influenced by these factors, although the effects may be more regional than local. Utility service areas often cross state lines. In addition, major utility power plants tend to be located along large waterways, many of which also form state boundaries. In the case of the Kentucky, Indiana, Illinois and Ohio we see extensive development of coal-fired power plants along the Ohio main stem, and along the lower Wabash which separates southern Indiana and Illinois. The 'corridor' of power plants placed along this region's major rivers has long been recognized as a significant geographic feature of the

Midwest.[45] This fact, along with knowledge of the quantity of utility-generated CO_2, provides strong support for the concept of regional mitigation studies.

The inventory of GHG emissions for Kentucky for 1990 was conducted on a county by county basis with all calculations resident within one Excel 5.0© spreadsheet.[46] Direct conversion of the 1990 spreadsheet to other years on the basis of projections of county by county population change was developed as a first approximation to future and past GHG emissions based first on a "status quo" scenario that assumed no significant change in gross domestic product or of any parameter other than that driven by population. Estimates for this scenario based on the average between moderate and high growth patterns, while admittedly unrealistic, are instructive in that they show how powerful a factor population is in making GHG projections for Kentucky. The results of these calculations are given in Table 4 in terms of gross emissions, and with carbon

Table 4. Historic and Projected GHG Emissions for the Commonwealth of Kentucky for a Population Driven Status Quo - No Technical Change Scenario

Year of Observation	Historic GHG Emissions tons CO_2 per year		Population Driven GHG Emissions tons CO_2 per year	
	gross	net	gross	net
1960	170,000,000	132,000,000	*****	*****
1970	180,000,000	142,000,000	*****	*****
1980	204,000,000	166,000,000	*****	*****
1990	206,000,000	167,000,000	*****	*****
2000	*****	*****	216,000,000	178,000,000
2010	*****	*****	225,000,000	187,000,000
2020	*****	*****	235,000,000	197,000,000

sequestration taken into account (net), assuming the rate for sequestration found for Kentucky for 1990 holds constant from 1960 through 2020.

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[45] Stukel J. J. and Boyd Keenan, *Ohio River Basin Energy Study ORBES Phase I. Interim Findings,* Grant No. R804848-01, Office of Research and Development, US EPA, Washington , DC, pp. 73-76 (1978).
[46] Spencer, H. T., *Kentucky Greenhouse Gas Inventory: Estimated Emissions and Sinks for the Year 1990,* University of Louisville, Speed Scientific School under contract with The Kentucky Natural Resources and

A more meaningful set of projections was obtained by applying a modification of the technological and economic changes suggested by Meyer and Lyons as a component of the Kentucky Outlook 2000 project.[47] This project was developed by the Center for Environmental Management (CEM) at the University of Louisville for the Kentucky Long Term Policy Research Center for the express purpose of examining "policy alternatives and the identification of directions for policy change that hold the promise of sustainable development that enhances both the socio-economic well-being and the quality of the physical environment of the people of Kentucky".[48] In many respects this project and the Kentucky Greenhouse Gas project share the same goals and, to a lesser degree, some of the same methodologies and constraints.

The forecasting process used in the CEM study relied upon two computer programs to obtain mathematical and environmental projections for the year 2025 using 1995 as a base year. The models applied were the REMI econometric forecasting model for Kentucky operated by the Legislative Research Commission, and the POLESTAR model provided by the Tellus Institute of Boston, Mass. POLESTAR was described as "a decision-support tool that links annual releases of pollutants to the air, water, and soils of a geographic area, rates of natural resource consumption and changes in land use patterns to levels of population and gross domestic product by major sector".[49] A number of "technical change" assumptions were built into the POLESTAR and REMI projections based on a review of the literature and current circumstances for Kentucky. Those of particular interest to the Kentucky GHG study are listed below as suggested for the year 2025:

1. The Burley quota will drop by 50 percent;

2. The demand for coal (eastern and western fields) will decline by 15 percent;

3. Fuel efficiency will rise by 25 percent for motor vehicles;

4. Vehicle emissions per unit of fuel will drop by 20 percent;

5. Demand for electricity for household lighting and appliances will drop by 40 percent;

Environmental Protection Cabinet using funds provided by the US EPA, Office of Policy, Planning and Evaluation, Federal Assistance No. CX822849-01-0 (1996).

[47] Meyer, P. B. and T. S. Lyons, *Forecasting Kentucky's Environmental Futures,* Kentucky Institute for the Environment and Sustainable Development, Center for Environmental Management, June 27, 1996.

[48] *Ibid.,* Meyers and Lyons, p. 1.

6. Total fuel use for space heat will drop by 20 percent;

7. Electricity consumption in the service sector will drop by 50 percent;

8. Industrial power use, outside of fuel consumption for transportation, will fall by 30 percent;

9. Use of natural gas or LPG in the transportation sector increases by a factor of 3;

10. Use of wood biomass increases by 25 percent in several sectors while other fuels (except for coal) drop proportionately.

Meyers and Lyons also suggested a significant decrease in the built environment required per capita, generally that portion of the land taken up with urban, commercial and industrial development; *i.e.,* roads, parking lots and buildings. The changes offered for 2025 AD were given by region with the assumption that forest lands would grow in response:

> Bluegrass 25 percent
>
> Central 15 percent
>
> Eastern 10 percent
>
> Western 15 percent

These changes were assumed to occur on their own and in the absence of policy changes made for the specific purpose of reducing, for example, the amount of emissions per unit of automotive fuel or the demand for electricity. Meyers and Lyons assumed that such "changes will be sufficiently attractive economically, as well as environmentally, to result in broad adoption of the new technology".[50] In making these assessments, however, these authors also assumed in some cases that the impact(s) of global warming and associated policy changes would play a part.[51]

Other changes not cited by Meyers and Lyons that may well occur without an additional policy push, and which could affect GHG emissions as well, are the reduction in fugitive CFCs and related compounds. These were shown in Phase I to be significant contributors for Kentucky.

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[49] *Ibid.,* Meyers and Lyons, p. 5.

[50] *Ibid.,* Meyers and Lyons, p. 36.

[51] *Ibid.,* Meyers and Lyons, item : "Coal Mining", p. 32.

The suggestions of easily adaptable technical changes made by Meyer and Lyons were incorporated, with some modification, into the population-driven scenario discussed above to give a first set of true baseline projections for the Kentucky Phase II project. The parameters applied are listed below. It is to be understood that the changes listed, an increase in the demand for electricity of 1.4 percent annually, for example, are assumed to be taking place in addition to increases due just to population.

1. The efficiency for use of residential fuels will increase by 10 percent;

2. Emissions per gallon of transportation fuel used will drop by 20 percent;

3. Miles per gallon of transportation fuel used increases by 10 percent;

4. The efficiency for use of commercial fuels will increase by 10 percent;

5. The efficiency for use of industrial fuels will increase by 10 percent;

6. The efficiency for use of electricity in the residential sector will increase by 10 percent;

7. The efficiency for use of electricity in the commercial sector will increase by 10 percent;

8. The efficiency for use of electricity in the industrial sector will increase by 10 percent;

9. The gross domestic product for Kentucky will increase by 1.50 percent annually;

10. The demand for electricity will increase by 1.4 percent annually;

11. Percent of electricity generated from direct coal combustion will drop by 10 percent;

12. Ninety percent of the coal-fired BTU load given up will be shifted to either natural gas or to coal-gas conversion systems;

13. Ten percent of the coal-fired BTU load given up will be shifted to oil;

14. The amount of coal-fired BTU load shifted to wind and solar will be inconsequential;

15. Use of biomass for power and heat increases by 10 percent;

16. Coal production increases by 15 percent;

17. Emissions due to fertilizer application drops by 10 percent;

18. Emissions due to manure management drops by 10 percent;

19. Emissions due to landfills drops by 10 percent;

20. Emissions due to sewer systems drops by 10 percent;

21. Fugitive emissions of CFCs drop by 20 percent;

22. Loss of HCFC-22 byproduct drops by 50 percent;

23. No net increase in methane capture by mining operations.

24. Net carbon sequestration will remain constant at 34,200,000 tons per year.

3.3 Phase II Master Spreadsheet Organization

Predictions 1 to 24 listed above, as incorporated into the Excel 5.0© spreadsheet developed in Phase I for the 1990 base year, resulted in a master spreadsheet for Phase II calculations.[52] Design details for this master spreadsheet are provided in the report appendix (8.2) along with an example "Policy Initiative" worksheet.

The division of electricity according to end use in Kentucky in 1990 is given in Table 5 along with the 1990 fuel split for electricity generation. The fuel split, as indicated by figures in the page center (Appendix 8.2), is recalculated with each change in year beyond 1990. The division in electricity end use, however, remains fixed in the spreadsheet with the numbers shown in Table 5. The division in electricity end use was determined using methodology developed in the Ohio River Basin Energy Study.[53] The principal data source used in making the calculations was the Department of Energy EIA data report tabulated through 1991.[54]

Table 5. Baseline Distribution of Electricity End Use and 1990 Fuel Split for Kentucky

Electricity	Percent of	Economic Sector	Percent of

[52] See Report Appendix

[53] Hartnett, James P. and Jan L. Saper, *Energy Consumption Patterns: Illinois, Indiana, Kentucky, Ohio, Pennsylvania and West Virginia,* Ohio River Basin Energy Study (ORBES), pp. 62 (1975).

[54] *State Energy Data Report 1991: Consumption Estimates,* Energy Information Administration, Office of Markets and End Use, U. S. Department of Energy, DOE/EIA 0214 (01), pp. 141, (May 1993).

Generation Power Source	Electricity Generated: 1990	for Distribution of Electricity	Electricity per Economic Sector
Coal	99.29	Industrial	47.00
Hydro-electric	0.29	Residential	24.00
Natural gas	0.25	Commercial	17.00
Distillate oil	0.17	Transportation	0.00
Solar	0.00	Losses	10.00
Wind	0.00	Export	3.00
Total	100.00	Total	100.00

3.4 Justification for baseline assumptions

The twenty-three assumptions that yield baseline technical and economic forecast, and the changes in population discussed earlier, are all speculative. The assumptions listed below are intended to represent fairly conservative estimates of trends that are likely to affect GHG emissions between 1990 and 2020. The results that come from these assumptions, however, are still important in that they do provide a starting point for policy change design. Changes in these figures, especially if applied to sectors with significant impact, can have a dramatic effect on the outcome of the baseline projection and, subsequently, on the focus of policy initiatives. Thus, it is important to review the merit of each.

3.4.1 Efficiency in the use of residential fuels will increase by 10 percent.

The efficiency of residential fuel use has been set to improve without the need of a policy push by at least 10 percent through the year 2020. A number of factors favor this change. It is anticipated that with the shift in population discussed earlier that a good deal of new housing will be developed. These homes will be built with codes that have been improved over the years to include improvements in the efficiency of energy

utilization[55]. Heating systems, especially the central heat generator, have also improved

dramatically in the past two decades. It is

anticipated that those older systems still in existence today will be completely replaced

by the year 2020. In addition, newer homes and developments are also expected to take

tree cover into account when given the opportunity. All of these factors, and the reality

that energy costs will rise, add together to ensure that the efficiency of residential fuel use

will go up.

3.4.2 Transportation fuels: emissions per gallon of fuel used will drop by 20 percent

The population of the Commonwealth is expected to shift toward a more urban

environment with greatest concentration along the main highway corridors. It is

anticipated that this in turn will result in the expansion of vehicle emission testing

programs and, in response to need, in the development of engines that produce less

carbon monoxide, particulates, and VOCs. The extent to which this will occur is difficult

to gauge but the direction of change is sure to be in the direction of a reduction.

Alternate fuels and combined systems using fuel cells, electrically powered

vehicles and clean burning fossil fuels are also expected to come along during the 30-year

period in question. These changes too are difficult to assess but they are certain to take

place. Many such vehicles, especially those fully electrically powered and those using

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[55] The phrase "improvements in the efficiency of energy utilization" may appear cumbersome to some. Indeed, the phrase is often abbreviated to read "energy conservation" or "energy efficiency," both of which may be more familiar to the reader. However, the phrases "energy conservation" and energy efficiency" are technically meaningless and do not appear in this report except in the instance of discussing EER (Energy Efficiency Ratings) values for modern appliances. The EER term is a US government creation stamped into the metal work on some appliances and cannot be avoided. The first abbreviation, "energy conservation," fails by virtue of a fundamental tenet of thermodynamics; namely, that energy (and mass) are always conserved regardless of what we do. We should not imply through our writings that we can improve in some way on this fundamental law. The second term, "energy efficiency," also fails by virtue of basic thermodynamic definitions; namely, that the term "efficiency" as applied to heat engines and heat exchange systems---automobiles, refrigerators, air conditioners, home heating units, power plants, *etc., etc.*--- refers to the efficiency of energy utilization. Mathematically, the term "efficiency" is equal to the absolute value of the work done by the engine, or heat delivered or removed by the exchange system, divided by the heat it has adsorbed or utilized in the process. Efficiency is a unitless term usually expressed as a percentage. You can buy a bottle of lubricant to make an engine work more efficiently, and thus to use energy more efficiently in producing work, but you cannot buy a bottle of "energy efficiency," nor can one utility sell electricity that is more efficient than electricity purchased from any other utility.

natural gas, are already on the road. Thus, the assumption that we will see a 20 percent reduction in emissions per unit of fuel burned appears quite reasonable.

3.4.3 Transportation fuels: miles per gallon of fuel used will increase by 10 percent.

Fuel mileage figures for vehicles on the road today far exceed those of two decades ago. There is every reason to expect this trend to continue in the future. Fuel costs and taxes on fuels will rise, and environmental constraints in addition to those directly associated with greenhouse gas emissions will also continue to develop. In addition, it appears probable that more people will find it beneficial to carpool if, as projected, population shifts to a more urban setting where parking can become a problem.

Vans and light trucks are projected to increase in number as well to produce some offset to the gains provided by increased fuel efficiency. As a consequence the efficiency in fuel consumption per vehicle mile has been held to an increase of only 10 percent.

3.4.4 The efficiency for use of commercial fuels will increase by 10 percent.

Excluding fuel used for transportation, commercial fuel use is expected to be more efficient for many of the same reasons as cited for residential users. Commercial establishments also have the need to maintain an adequate profit margin. This association with market pressures leads naturally to costs-cutting steps, not the least of which is in the area of improved energy end-use efficiency.

3.4.5 The efficiency for use of industrial fuels will increase by 10 percent.

The same considerations made for residential and commercial users will apply to industrial systems. In addition, it must be anticipated that severe constrictions will be placed on industrial emissions in the coming future for the sake of controlling air toxics and fine particulates. This fact, and the reality that Kentucky's industries now face true global competition, leads to an estimate of 10 percent increase in the efficiency of industrial fuel use. The direction of change and its magnitude will be driven by the need to cut costs and meet environmental restrictions.

3.4.6 Efficiency in residential electricity use will increase by 10 percent.

A wide range of new energy-efficient appliances and lighting systems are anticipated for the future. In many cases these will become the only items on the market. It is highly probable that these fixtures will result in a minimum of a ten percent increase in the efficiency of residential electricity use, especially in the area of cooling. Improved insulation and building design are also expected to have an ongoing impact in the direction of increased efficiency of heat transfer.

3.4.7 Efficiency in commercial electricity use will increase by 10 percent.

Commercial business are expected to improve on electricity end-use efficinecy for much the same reasons as discussed above for residential users. In addition, commercial institutions have to consider the added incentive of profit motive and competitiveness. Savings in energy costs will become an ever more important part of this mix in the future.

3.4.8 Efficiency in industrial electricity use will increase by 10 percent.

The largest fraction of electricity used in Kentucky in 1990 was by the industrial sector at 47 percent. Thus, any significant change in this portion, or increase in efficiency of the use of electricity in this sector, will have a measurable impact. Market forces and competition will force the same end-use efficiency efforts on industry as on the commercial sector.

3.4.9 The annual increase in gross domestic product for Kentucky will be 1.50 percent through 2020.

Meyers and Lyons in their forecast for the year 2025 used figures for efficiency improvements similar to those selected for the phase II baseline projection, though possibly not quite as conservative. These authors consequently projected through the REMI model that the Commonwealth's total gross domestic product would increase by 47 percent through 2025.[56] An annual increase of 1.50 percent gives an increase of 45 percent through 2020. Subsequently, this figure was taken as reasonable for the Phase II baseline projections. Population increases were held to 5 percent by Meyers and Lyons

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[56] *Ibid.,* Meyers and Lyons, p. 47.

which is somewhat modest as compared to the figure of 15 percent used here (the average of high and moderate growth projections). A figure of 45 percent increase in total gross domestic product for 2020 used in this study is thus quite conservative and implies a GDP growing somewhat independently of population. This figure of 45 percent could go significantly higher if, as is anticipated, the focus of industry shifts ever more toward increased productivity, resource conservation and expanded profit margin.

3.4.10 The annual demand for electricity will increase at a rate of 1.4 percent.

Meyers and Lyons assumed for their technical change scenario that electricity consumption in the service sector would fall by 50 percent through 2025.[57] They also assumed that electricity use would drop by 33 percent in light industry, and by 40 percent for household lighting and appliances. These assumptions together with others listed in section 2.2 gave a predicted increase in total energy demand of 18 percent.[58] This baseline scenario was restructured to take a number of additional factors into account: increased timbering, secondary wood processing, additional manufacturing employment and expansion of the tourism industry.[59] This resulted in a total energy demand increase of 33 percent. The mix of energy resources relied upon to provide this increase is assumed not to change.[60]

Although the exact figures are unknown, it is highly probable that the demand for electricity will increase regardless of more efficient use. Thus, and partly in response to the POLESTAR and REMI estimates produced by Meyers and Lyons, a figure of 35 percent increase has been selected for the Phase II baseline.

The Energy Information Administration has also conducted a microeconomic analysis on utility restructuring using the National Energy Modeling System (NEMS). The reference case for this study assumed a 1.4 percent annual growth rate in electricity sales which in turn computes to 47 percent increase in demand through 2020 AD.[61] This

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[57] *Ibid.,* Meyers and Lyons, p. 37.
[58] *Ibid.,* Meyers and Lyons, Table 2, p. 12.
[59] *Ibid.,* Meyers and Lyons, p. 7.
[60] *Ibid.,* Meyers and Lyons, p. 70.
[61] White, Jeffery P., *Electric Utility Restructuring and Environmental Policy,* Edison Electric Institute, September 12, 1997, p. 8.

figure exceeds the choice made by Meyers and Lyons but has been adopted for this study on the basis of its being derived through analysis of utility industry restructuring issues.

3.4.11 Ten percent of the coal-fired BTU load for generation of electricity will be shifted to alternate fuels other than natural gas.

It is anticipated that major producers of greenhouse gases, particularly the electric utilities, will shift as much of their generation load to other fuels as economically possible.   The shift will be to natural gas and, to a lesser extent, to distillate oils. This change will likely occur in the absence of new policy initiatives. Concern over fine particulates and the specter of pressure from international treaties regulating carbon dioxide emissions are expected to be the driving forces. Some aspects of utility restructuring are also expected to impact this industry. Collectively, these factors to make the circumstances of prediction for the utilities extremely fluid.

3.4.12 Ninety percent of the BTU load given up by coal will be shifted to natural gas or to coal-gas conversion systems.

Utilities will gain the most benefit in terms of CO_2 emission reduction by shifting to natural gas. There are 31.9 pounds of carbon per million Btu of natural gas, 44.0 pounds per million Btu for distillate fuels, and 56.0 pounds per million Btu for bituminous coal.[62] Natural gas supplies, however, have declined in recent years. Deregulation at the well-head may bring improvement in gas supplies in the future, and supplies may also increase through the development of coal to gas conversion systems. Still, the question remains: "Will there be a supply of natural gas in the future adequate to support a major shift of utility base-load from coal to gas?" In 1990 Kentucky's utilities used 1,900 million cubic feet of natural gas, a fraction of the 75,000,000 million cubic feet produced in the state in that year. The baseline projection for 2020 suggest, however, that if 10 percent of the coal utility base is shifted to natural gas-coal gas conversion the demand will be for an additional 100 billion cubic feet per year. This demand, given the probable improvements in combined-cycle gas burning technology, has the appearance of being reasonable.

3.4.13 Ten percent of the BTU load given up by coal will be shifted to oil.

The shift to distillate oils is envisioned to be considerably smaller, and thus much easier to accept in terms of fuel supply. A shift to oil, however, will not provide as much benefit as a shift to gas and for this reason is considered to be only minimally plausible at best. A shift, if it occurs at all, will likely be in the area of peaking facilities.

3.4.14 The coal-fired BTU load shifted to solar and wind power will be zero.

No significant shift in coal-fired utility base to wind or solar power in the absence of policy initiatives is envisioned. The wind resource in Kentucky is relatively poor, and the economics of solar electricity are projected to preclude its use on a large scale unless compensating policies are put in place.[63]

3.4.15 Use of biomass for power and heat will increase by 10 percent.

It is anticipated that the use of biomass such as sawdust and wood residues will increase somewhat in the wood products industry. Meyers and Lyons assumed that biomass would provide 25 percent of the needed power for developing wood processing industries, food industries, and some heavy industries as well.[64]

3.4.16 Coal production increases at an annual rate of 0.5 percent.

The major factors contributing to an increase in coal production are the expanding economy and the anticipated restructuring of the electric utility industry. An increase in the use of coal as a chemical feedstock is also probable. For these reasons, coal production is assumed to increase by 15 percent by the year 2020. Meyers and Lyons suggest otherwise citing improved efficiency in the generation of electricity and restrictions due to global warming.[65]

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[62] *State Workbook: Methodologies for Estimating Greenhouse Emissions,* US EPA., Policy, Planning and Evaluation, EPA 230-B-95-001, Revised January 1995, pp. 1-11.

[63] Conner, Glen, Snow, Richard K. and Mary M. Snow, *Summarization of Kentucky Wind Data;* Kentucky Division of Energy Memorandum of Agreement No. D 678; Kentucky Climate Center, Western Kentucky University, Bowling Green, Kentucky, June 1993.

[64] *Ibid.,* Meyers and Lyons, p. 37.

[65] *Ibid.,* Meyers and Lyons, p. 37.

3.4.17 Emissions due to fertilizer applications drops by 10 percent.

It is anticipated that tobacco production will drop in the future, perhaps by as much as 50 percent by 2025. Tobacco, a major cash crop for Kentucky, is also a major user of fertilizer. Other changes that would affect fertilizer application are improvements derived from current research directed toward reduction in the application of chemicals in agriculture. In addition, it is probable that the current trend in loss of farm acreage to urban development will also continue in the future. Selection of a 10 percent reduction figure thus appears quite reasonable.

3.4.18 Emissions produced by livestock manure will drop by 10 percent.

Manure management, especially that associated with large industrial farms, will likely be regulated more so than today. It is probable that emissions due to manure systems will drop. A figure of 10 percent has been taken to reflect this belief. The regulatory changes most likely to come are those associated with water treatment systems, stream pollution, and odor control.

Farm animals also produce a small amount of methane. These have been accounted for in the baseline scenario on the basis of population only. No technological change could be found which could reasonably be expected to affect this parameter.

3.4.19 Emissions due to landfills will drop by 10 percent.

The capture of gas (methane) at modern landfills either for flaring or some more productive use is probable for the future. Older landfills are expected to stay as they are. These considerations, along with the current practice of recycling in the major cities, and given developments in reducing packaging waste, lead to an estimate of 10 percent reduction for landfill gas emissions.

3.4.20 Emissions due to sewer systems drops by 10 percent.

It is anticipated that more septic tank systems will be phased out in the future. In addition, it is highly likely that wastewater treatment systems will be placed under the rule of Title V regulatory action. The is also a tendency now for consolidation of smaller systems into larger facilities for the purpose of providing better treatment. A drop in

emissions of 10 percent was chosen to account for these changes, although the change could be greater.

3.4.21 Fugitive CFC emissions will drop by 20 percent.

It is probable that fugitive CFC emissions may be removed entirely by 2020, at least in this country. International protocols are now in place regulating the manufacture of these materials, and research to find replacements is intense.

3.4.22 Loss of HCFC-22 by product drops by 50 percent.

The major Kentucky manufacturer of chlorinated refrigerants, the E. I. duPont company in Jefferson County, has already reduced its emissions rate of HCFC-22 byproducts as compared to 1990. This trend is expected to continue as production processes are modernized and as research continues to develop replacement refrigerants that have less impact on the atmosphere.

3.4.23 Coal mine capture of methane will be insignificant

Coal-bed methane capture is limited in Kentucky. Issues pertaining to ownership of the gas rights involved, costs of production and quality of the product are all factors. Some efforts have been made to address this problem but absent a major policy shift it is deemed unlikely that any significant capture will take place in the foreseeable future.

3.4.24 The gross rate of carbon sequestration remains constant at the 1990 amount.

The 1990 Greenhouse Gas Inventory for Kentucky (Phase I report) estimated that 3.2 million tons of CO_2 equivalent were absorbed by annual growth of Kentucky forests, 35.0 million tons from the growth of trees on abandoned lands - most of which is former farmland that is returning to forest - and that 4.0 million tons are released from the conversion of land as a result of mining, for a net absorption of 34.2 million tons of CO_2 equivalent in 1990.[66] If it is assumed that the major sequestration trends described in the

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[66] Spencer, H. T., *Kentucky Greenhouse Gas Inventory: Estimated Emissions and Sinks for the Year 1990,* University of Louisville, Speed Scientific School under contract with The Kentucky Natural Resources and Environmental Protection Cabinet using funds provided by the US EPA, Office of Policy, Planning and Evaluation, Federal Assistance No. CX822849-01-0 (1996), Table 34, p.133.

Phase I report remain in place, the gross rate of carbon sequestration projected for 2020 would be equal to that estimated for 1990 ($35.2 + 3.2 = 38.2$ million tons CO_2 per year).

The amount of forest land cleared for mining is expected to increase slightly (see section 3.4.16), along with the amount of land taken up by urbanization. The majority of the land taken for urban growth in Kentucky between 1990 and 2020 will come from farmland located along the major interstate corridors connecting Louisville-Lexington-Cincinnati, and along the corridor south and west of Louisville along I-65 (see Figure 1). Crop and pasture lands do not contribute significantly to CO_2 emissions from land conversion, but forest lands do. Thus, in the base case described above it is anticipated that emissions due to land conversion will increse slightly as a result of the slight increase in coal mining.

The increase in emissions due to land conversion from mining is accounted for in the policy initiatives spreadsheet. Emissions due to conversion for urban land are not, on the assumption that most if not all of this property is coming from existing farm property. Net emissions are determined in the spreadsheet by subtracting the 38,200,000 figure noted above from gross emissions.

3.5 2020 Baseline Scenario Greenhouse Gas Projections

The output of the baseline scenario resulting from assumptions 3.4.1 through 3.4.24 is given in Table 6 along with the output for the 1990 base year. (The reader should note that the significant digits shown in this table for emission projects are being carried for accounting purpose only. The figures are not considered to be actually accurate to the number of decimal places shown.) The distribution of emissions per county for 1990, for the 2020 baseline, for the 2020 baseline normalized to 1990, and for the 2020 baseline per capita are shown in Figures 3 through 6.

Figure 7 depicts the range of emissions for status quo, baseline and advanced technological change scenarios. In the status quo scenario shown in Figure 7 population, electricity production, and gross domestic product increase at baseline percentages to force a dramatic rise in emissions. These changes occur in the absence of any ameliorating technical change, including utility fuel switching to natural gas. The bottom line in Figure 7 accomplishes the opposite task by doubling the percentages beneficial to

emission reduction to give a scenario twice as effective as the baseline. In this last case, fuel switching is also included.

Several features of the projections and data shown in Figures 3 through 7 are notable:

1. Figures 3 and 4 suggest that the distribution of emissions per county will remain essentially the same in going from 1990 to the 2020 baseline projections;

2. Figure 5, when compared to Figure 2, suggests a strong effect due to population shift predicted for 2020, with intense emission changes coming along the major highway corridors;

3. Figure 6 suggests a fairly constant emission rate per capita for the Commonwealth, except for highly industrialized counties;

4. Figure 7 suggests a dramatic increase in emissions in the absence of technical change, and also that significant reductions can be achieved by doubling the beneficial percentages in the baseline scenario.

Figures 3 through 7 and Table 6 are organized as a group at the end of this section for the sake of convenience to the reader.

Table 6. Projection of 2020 AD GHG Baseline Emissions Calculated on the Basis of Changes Listed in Elements 3.4.1 through 3.4.24 Superimposed over Predicted Population Changes for an Average Growth Scenario

Sector	1990	2020	30 yr.
	Equivalent tons	Equivalent tons	percent

	CO$_2$ per year	CO$_2$ per year	change
Residential fossil fuels	5,950,574	5,987,943	0.60
Transportation fossil fuels	28,902,812	29,474,988	2.00
Commercial fossil fuels	2,773,997	4,103,356	47.90
Industrial fossil fuels	16,657,534	24,848,206	49.20
Utility coal use	76,449,370	109,215,955	42.90
Utility oil use	104,667	1,119,614	969.70
Utility natural gas use	108,807	6,425,543	5,805.50
Gas and oil production	8,593	9,861	14.80
Natural gas distribution	433,697	740,659	70.80
Oil refinery storage	16,388	18,806	14.80
Coal mine production	19,801,826	26,132,044	32.00
Chemical plant production	19,485,006	13,756,647	-29.40
Conversion of land	4,025,273	5,312,018	32.00
Farm animals	3,420,189	3,924,826	14.80
Manure management	827,839	854,985	3.30
Fertilizer application	761,757	786,736	3.30
Sewer systems	176,493	182,280	3.30
Landfill emissions	2,773,457	2,864,404	3.30
Fugitive CFCs	22,842,031	20,969,834	-8.20
Total as CO$_2$ equivalent	205,520,310	256,728,755	24.90
Carbon sequestration	(-38,200,000)	(-38,200,000)	0.00
Net CO$_2$ equivalent	167,320,310	218,528,755	30.60

Figure 3. 1990 Base Year Emission Rates in Tons CO2 per Year

The base year (1990) emission rates per county were estimated in the Kentucky Phase I project completed in May 1995. As noted in the report text, the master spreadsheet used herein in Phase II was developed from the Phase I equation base. These functions were taken by and large from the standard EPA Workbook: Methodologies for Estimating Greenhouse Gas Emissions, EPA 230-B-95-001, January 1996. The distribution of emissions by county shown in Figure 3 are provided on a logarithmic scale, demonstrating once again the wide range in emission rates per county. These emissions are largely population driven, but also are influenced by the location of industry, coal-fired electricity generation stations and by the locations of active coal mining. In addition, all but one of the counties generating in the range of 10,000,000 tons per year either hold a major highway, or, if not, at least border a county that does.
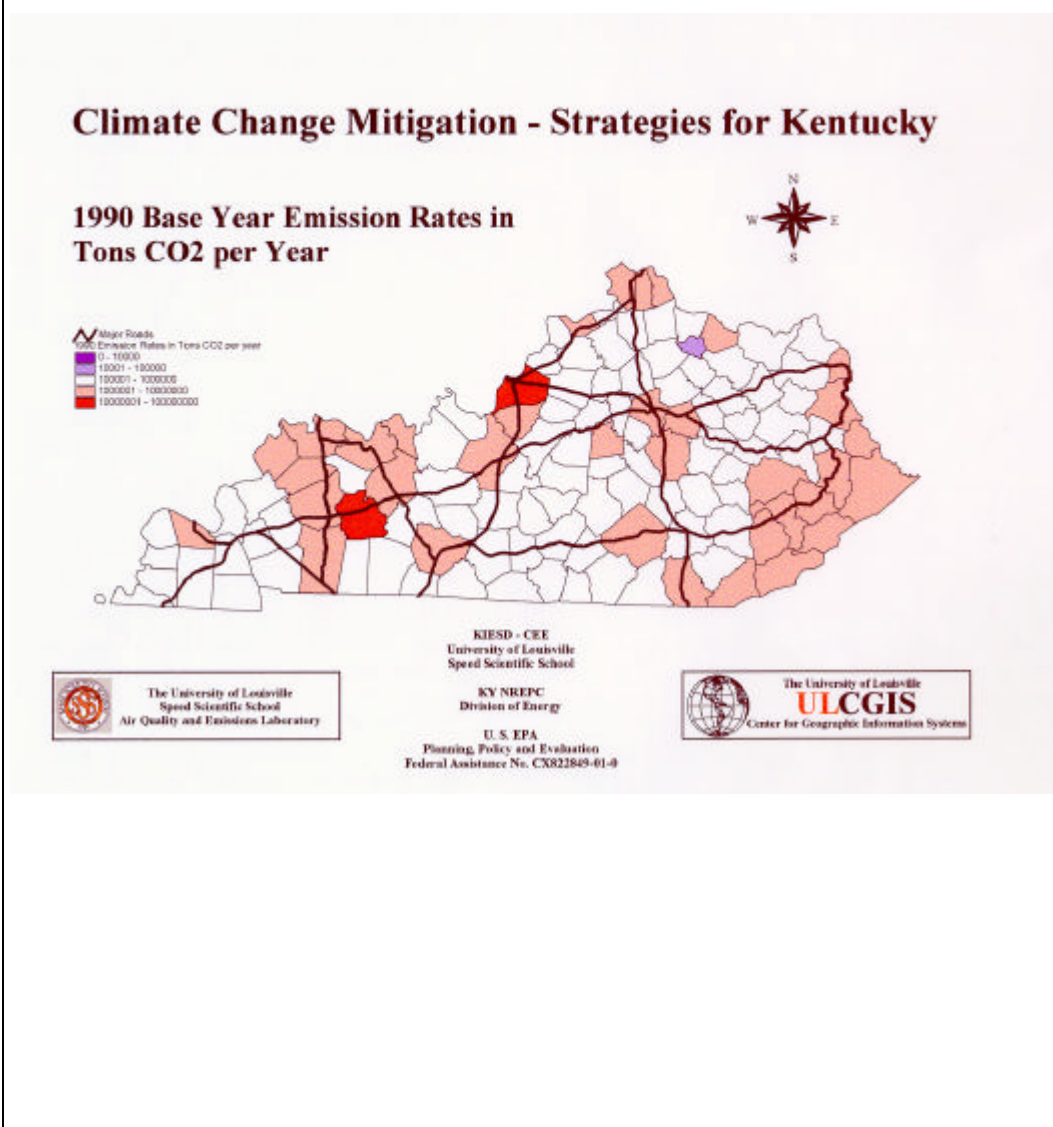
Figure 4. 2020 Baseline Emission Rates in Tons CO2 per Year

The 2020 projections show an additional four counties with emissions in the range of 10,000,000 tons per year as compared to the 1990 base year. In addition, one county (Carroll) is added at the range of 10,000,000 to 100,000,000 tons per year. All new counties in the high production group hold a major highway.

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2020 Base Case Projected Emissions Rates in Tons CO2 per Year
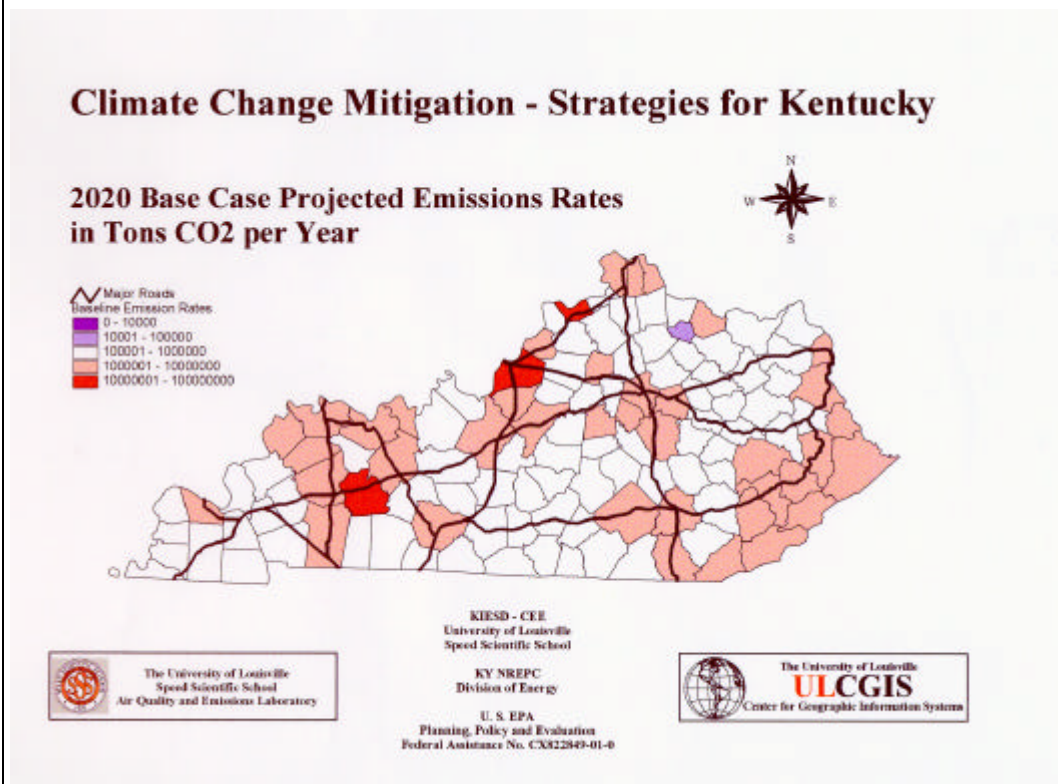
Figure 5. 2020 Baseline Emission Rates Normalized to 1990 Base Year

       The dichromatic presentation in Figure 5 reveals a pattern of growth in emissions favoring the more developed and industrialized regions of the state, particularly in the triangle formed by the major highways connecting Louisville, Lexington and Covington (Cincinnati). Approximately half of the Commonwealth's counties, including those of the eastern coal field and areas dominated by agriculture, show only modest increases in emissions. Some, a total of 17, show no increase at all, or an actual drop in output.
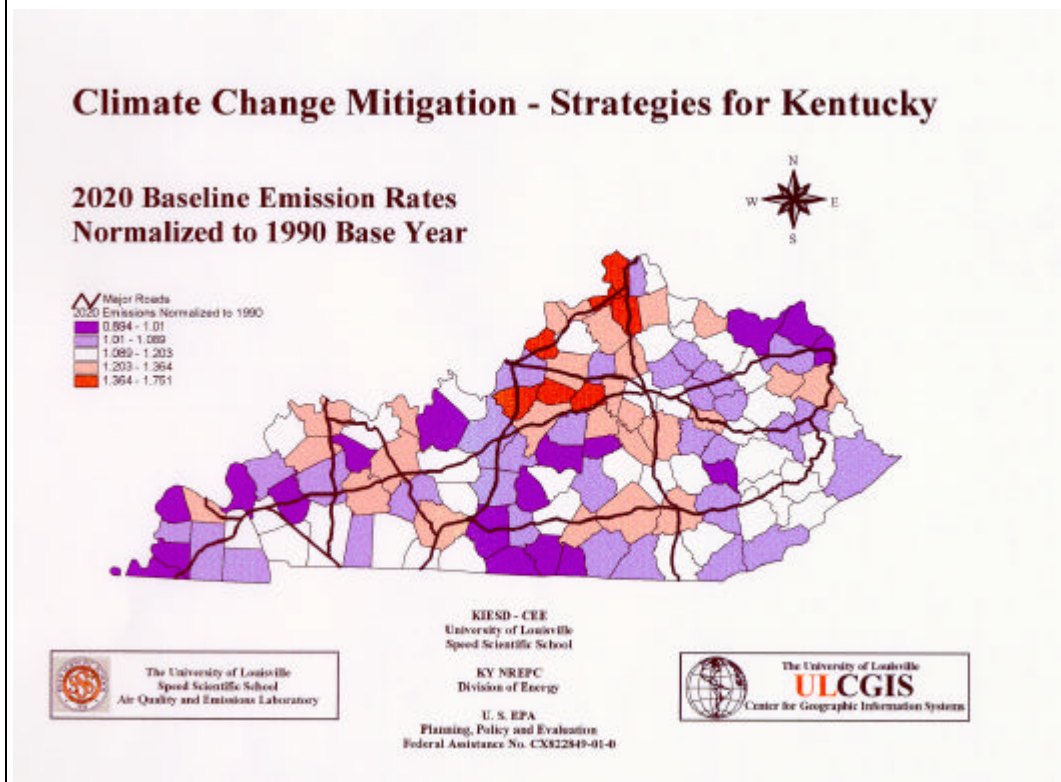
Figure 6. 1990 Base Year Emission Rates per Capita

Emission rates per person are provided on a county basis in Figure 6 for the 1990 base year, the last year for which actual census data is available. The results are revealing in that they show that per capita, the counties show remarkable similarity. Only those counties with active mining, coal-fired utilities and heavy industry stand out. Only six out of the one hundred and twenty Kentucky counties stand out as producing more than 200 tons per year per person.
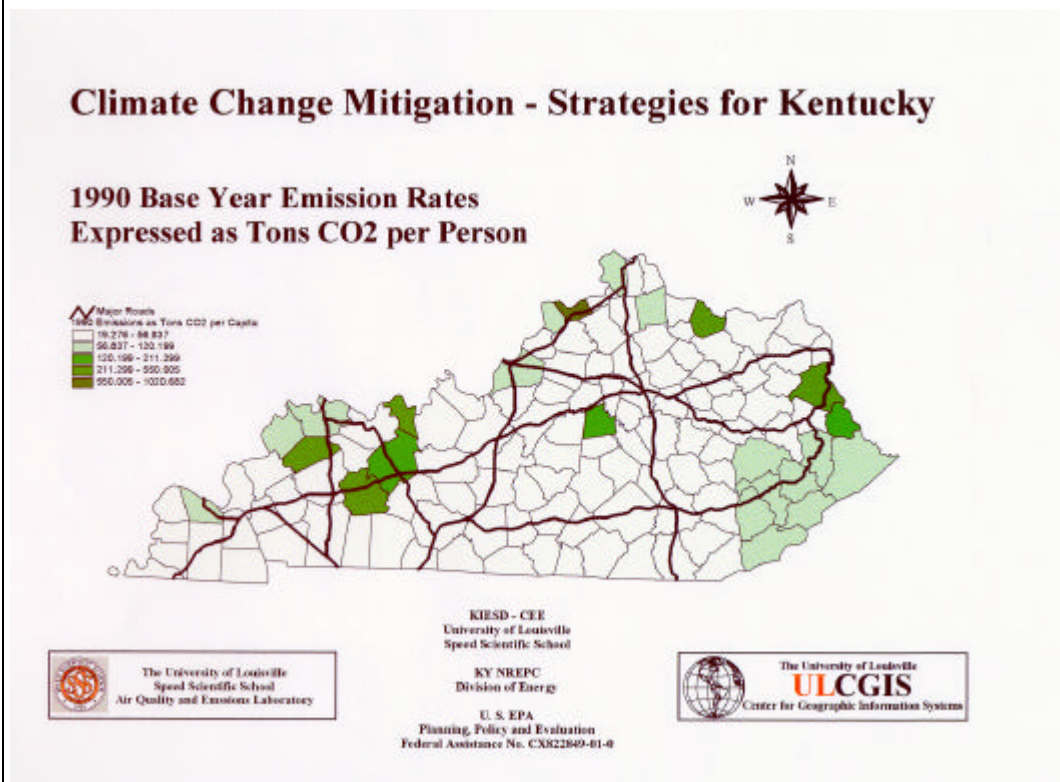
Figure 7. Scenario Comparisons for Greenhouse Gas Emission Rates: 1990 to 2020

The dotted line traced across the bottom of Figure 7 shows the 1990 base year emission rate. This rate has been suggested as the target value to stay even with, if not below. The next line up (blue) provides the rates of production for a scenario in which all beneficial assumptions described in section 3.4.1 to 3.4.23 have been doubled. This results in an emissions rate in 2020 15 percent over the 1990 level The middle line (green) indicates the increase expected for the 3.4.1 to 3.4.23 baseline assumptions as they stand. This results in an emissions rate in 2020 26 percent over the 1990 level. The top line (red) demonstrates the impact of a status quo scenario. In this scenario there is no fuel switching in the utility industry, and no improvement in end use for electrical power or fossil fuels. This scenario suggest a 37 percent increase in emissions.
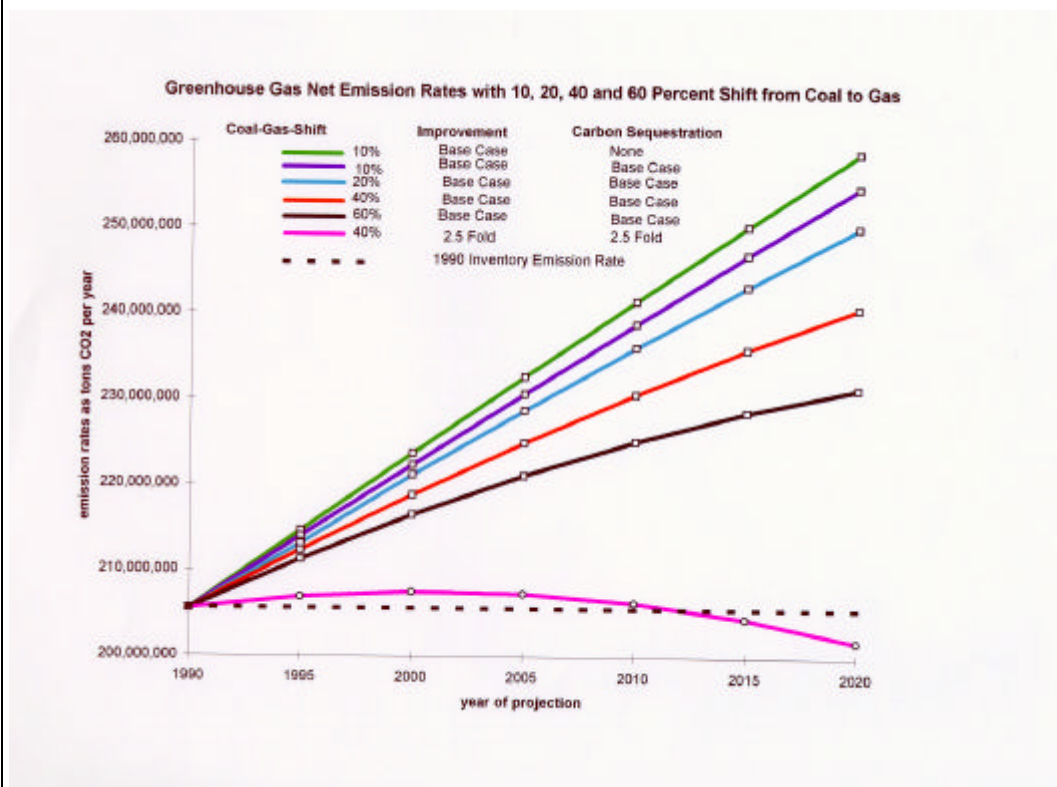
3.6 Comparison of the Phase II Baseline to Other Studies

Meyers and Lyons project a 9 percent increase in CO_2 emissions between 1995 and 2025 assuming a 5 percent population increase and applying the considerations of the restructured baseline scenario discussed above.[67] Application of a 5 percent increase in population to the baseline projections for the Kentucky Phase II study gives a 8.0 percent increase through for 1990 to 2020 which is in reasonable agreement considering the nature of the projections and assumptions used. Indeed, it appears that the two studies essentially reflect the same outcome in terms of percent of increase even though they use completely different means of calculations.

The actual amount of CO_2 estimated by the two studies are also appear to be in reasonable agreement. Meyers and Lyons projected CO_2 emissions of 296 megatons for 2025 for their restructured scenario. The Kentucky Phase II project estimate for 2020 is 258 megatons for a 15 percent population increase and assuming a 10 percent shift to natural gas-coal gas in the utility sector to give a base of 89 percent coal, 9 percent natural gas-coal gas, 1 percent oil and 0.2 percent hydro. The Kentucky Phase II estimate in the absence of a coal to gas-oil shift was found to be 263 megatons for a 15 population percent increase.

The rate of increase in carbon emissions for 1994 to 2015 is shown in Figure 8 for the base case, the base case with a doubling of benefits, the technical no-change scenario, and for the increase projected nationally by the EIA taking restructuring into account (see Table 6). Taken together, it is fair to say that the figures developed for the Kentucky Phase II project compare favorably with what might be expected on the basis of national estimates. If anything, the Phase II projections suggest a slightly lower growth potential for Kentucky than the national figures but the differences are not large.

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[67] *Ibid.,* Meyers and Lyons, Table 10.,p. 37.

Figure 8. Comparison of Phase II Projections for Carbon Emissions to National EIA Projections

The Figure indicates that the scenario without technical change or benefits comes closer to the national figures that the Phase II base case or base case with a doubling of benefits.

Greenhouse Gas Gross Emission Rates:1990 to 2020

Legend:
- Base Case without any Technical Change
- Base Case
- Base Case with a Doubling of Benefits
- 1990 Inventory Emission Rate

Y-axis: emission rates as tons CO2 per year
X-axis: year of projection
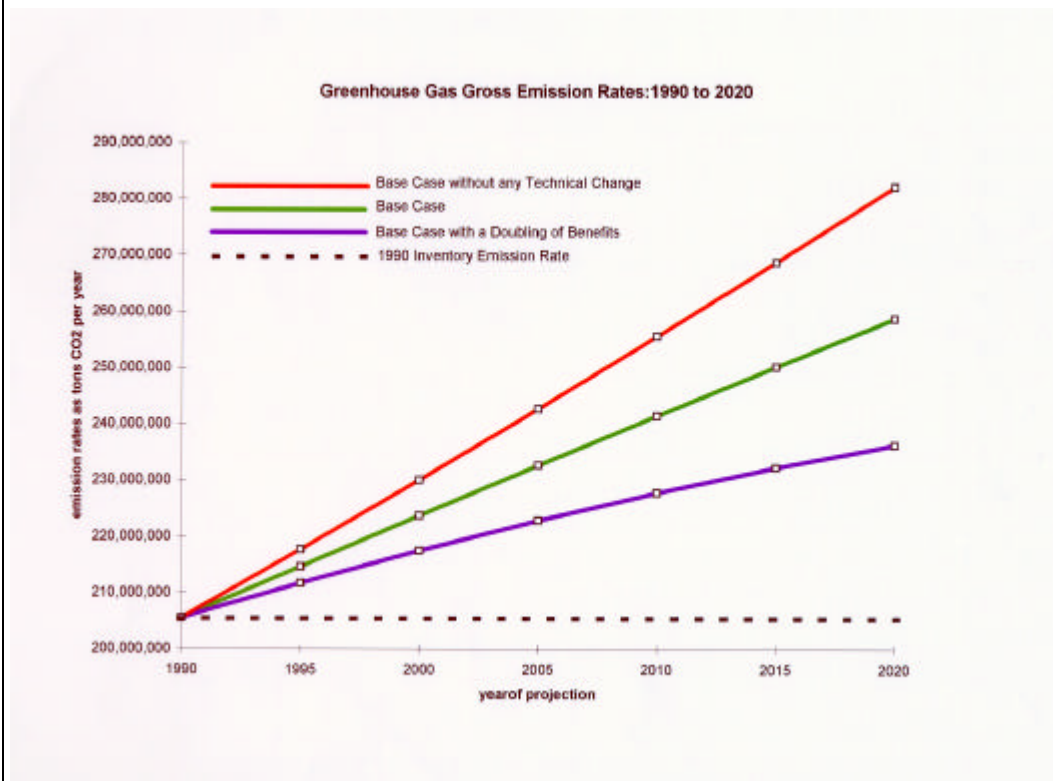
4. ADVANCES IN EFFICIENCY OF ENERGY USE

Estimates vary as to how much the developed countries can cut energy consumption. Smil proposes that a reduction of one-third is possible over the next generation among the world's more affluent societies, and one-half by 2050.[68] A reduction of one-third in energy consumption, if accomplished in Kentucky over the next 30 years, would have a significant impact on greenhouse gas emissions. The technological advances that could make this possible are briefly reviewed below.

4.1 Methods for reducing the demand for electricity in the residential sector

The principal uses of electricity in the residential sector are for heating, cooling and appliances. A wide range of energy saving techniques exist, many of which both enhance the resale value of a private home and, at the same time, reduce the cost of home operation. Energy costs for a home can exceed the mortgage if not managed wisely.

Fortunately, many improvements can be achieved through education, planning, proper maintenance and wise purchase of energy-efficient appliances. The listing below provides some obvious examples, and all of these have the potential of paying for themselves.

4.1.1 Lighting systems

Approximately 15 percent of the electricity used in a private home is for lighting.[69] A sizeable fraction of the electricity used for lighting, however, is lost as waste heat or through poor room lighting design. A number of new lighting systems are now available. Compact fluorescent lights are 3 to 4 times more efficient than regular incandescent lights and these last many times longer. Many of these lighting systems, also known as "green lights" because of their environmentally favorable ratings, will fit into a regular incandescent socket and produce light of the same or better quality.

Lighting plans for a private home are also effective in reducing the waste of electricity. Oversized outdoor lights can be replaced with smaller 50-watt reflector

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[68] *Cycles of Life: Civilization and the Biosphere* by Vaclav Smil, Scientific American Library, 1996, p. 198.

systems. Night lights can be reduced to 4 to 7-watt bulbs. Lighting zones can be developed in the home to concentrate lighting in work areas while leaving areas less used with reduced illumination. Light-colored walls and furnishings also reduce the demand for lighting.

A number of automatic cut-off systems such as motion detectors, timers and photocells are now available to sense when a lighted space is not in use. These systems turn lights off when demand drops which is especially valuable for outside lighting systems.

4.1.2 Home appliances

The balance of electricity used in the private home is used for appliances, for example; clothes washers, televisions, computers, refrigerators and ovens. Electricity in this sector comprises 20 percent of the total energy used in the home[70] This demand can be effectively reduced, especially for air conditioners and hot water heaters.

Average maximum temperatures in July in Kentucky range from 90 to 94 °F in the far western part of the state to 80° to 84°F in the east. The average maximum value for this month ranges from 85° to 89° F over most of the central region. Mean temperatures for July range from 80° to 81°F in the west to 74° to 75 °F in the east with the central region ranging from 78 to 79 °F.[71] A thermostat controlling the home air conditioner set in the range of 78 °F which is just below the regional average for most of the state as compared to a more typical 72° F could save as much as 40 percent of the energy cost for cooling. Timely maintenance of the system will further improve its efficiency of operation. Judicious choice of on-off cycles for room air conditioners are of benefit as well, as are fan speed settings and variations in air circulation systems. Insulation, caulking and weather stripping are also of obvious benefit. These are discussed below in the section dealing with reduction of residential fuel use.

Hot water heaters, if electrically operated, are significant users of energy. Temperature settings in the range of 140° F are typical of a newly installed hot water

[69] *Tips for Energy Savers,* U. S. Department of Energy, DOE/CE-0231, p. 18 (1995).
[70] *Ibid,* DOE/CE-0231, p. 20.

heater. A setting of 120° F, however, is adequate in most cases and should be kept at that level if possible. As much as 18 percent of the energy used can be saved in this way. Elimination of leaky faucets, wise management of dishwashers and of washing machines, and proper maintenance are also reasonable ways of reducing waste of energy.

The Department of Energy tests appliances for efficiency and the Federal Trade Commission develops labels for these items accordingly. The labels contain valuable information about the energy use of the equipment and should be studied carefully before a purchase is made. Energy use is measured in either dollars spent per year for operation, on in Energy Efficiency Ratings (EER values). The higher the EER value the better the appliance. The differences can be highly significant. For example, a central air system rated with an EER value of 10 will use 50 percent more electricity than a unit rated at 15.[72]

4.1.3 Policy initiatives for reducing residential demand for electricity.

A number of policy initiatives are available to facilitate home energy savings. Some of these are specific for the conservation of electricity; others provide benefits in several areas. Many are already in operation in the state. Those considered to be the most beneficial are listed below.

4.1.3.1 Education programs to provide information on electricity savings

Education programs can be an effective means of altering the behavior patterns and life styles that lead to energy waste. Programs showing the way to cost savings are the obvious ways of developing this area. The programs can be offered through a wide range of agencies, and they should be designed to reach all segments of the Commonwealth's population. Education programs take some time to take effect, but once in place and operational, they should be an effective and long lasting means of reducing greenhouse gas emissions.

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[71] University of Kentucky College of Agriculture, Agricultural Weather Center, Department of Biosystems and Agricultural Engineering, http://wwwagwx.ca.uky.edu/ down loaded July 15, 1997, 0930 EST
[72] *Ibid,* DOE/CE-0231, p. 21.

4.1.3.2 Tax incentives for residential electricity savings

Sales taxes incentives for appliances with high EER values as compared to low could prove beneficial in reducing the residential demand for electricity.   In addition, income tax deductions could be granted for the cost of retrofitting existing homes to achieve more energy-efficient systems. Income tax deductions could also be developed for homeowners who show a reduction in energy use.

4.1.3.3 Utility support for reduction in residential use of electricity

In addition to tax incentives, it is also possible that the region's utilities could provide incentives as well through demand side management (DSM) programs. These incentives might take the form of rebates or low-cost financing for the purchase of energy-efficient appliances, installation of devices that control the timing of certain appliances' operation, assistance in upgrading the efficiency of older homes or those whose residents are poor, and other programs. Unfortunately, such programs are becoming less common as utility restructuring approaches.

4.1.3.4 Potential savings in the use of residential electricity

Policy initiatives leading to significant savings in residential use of electricity will in time translate into a reduction in the increase in electricity production set at 35 percent for the baseline projections. It is reasonable to assume that through tax incentives, through the update of building codes, through educational programs, and through utility based incentives a concerted effort in this area could reduce the residential demand for electricity, but it is impossible to estimate the exact effect that this reduction will have. Utilities may well find it quite profitable to sell the electricity saved on other markets, a possibility that will be enhanced with deregulation. Still it appears reasonable to assume that some reduction in residential use of electricity will result take place. A 10 percent drop in addition to the 10 percent baseline reduction per year through the year 2020 would result in a savings of 800,000 tons of CO_2.

4.2 Methods for reducing fuel use in the residential sector.

Residential fuel use is concentrated in three critical areas: home heating, cooking, and the operation of hot water heaters. Heating systems are the principal users and thus offer the most benefits in terms of potential savings.

4.2.1 Home heating systems

Considerable savings in home heating can be achieved by fairly simple procedures, many of which are currently practiced by a portion of the population. Not turning on the heat until necessary is one option, along with keeping the thermostat at a temperature lower than that of historic practice. Proper maintenance of heating equipment and air circulation systems is also of benefit. Purchase of a more energy-efficient furnace, or of a heat pump in place of an electric heating system, will likely provide the most savings. Some modern gas furnaces transfer as much as 95 percent of the available combustion heat from natural gas. Similar efficiency figures for older systems vary from 50 to 75 percent.

Home insulation, caulking and weather-stripping are very effective means of achieving energy savings. The northern and central part of the state is listed as having mean annual heating degree day totals in the range of 4,500 to 5,000. The portion of the state from the central zone to the south has heating degree day totals in the range of 4,500 to 4000. A thickness of fiberglass batts, mineral fiber or cellulose fiber to give R-values of 38 is recommended for ceilings below ventilated attics for zones in the 4,000 to 5,000 heating degree totals for homes heated by natural gas, oil or by a heat pump. Insulation thickness to give R-values of 19 are recommended for floors over unheated basements and crawl spaces, R-11 for exterior walls. Few homes in Kentucky, especially those constructed prior to modern building codes, meet these standards.

Retrofitting, or weatherizing, for energy savings by caulking and weather-stripping can be of tremendous benefit. Leaks of warm air and intrusions of cold air from the outside in homes that have not been weatherized can account for 30 to 40 percent of the heat lost. Thus, approximately one-third of the heating cost is wasted for the home that has not been weatherized. Caulking, especially around window frames, doors, pass-

through plumbing and wiring, and along the major joints can reduce this loss by a half or more.

The construction of new homes built to modern codes or to more efficient designs can show dramatic improvements in energy end-use efficiency. Super-insulated homes, homes where insulation and construction techniques meet to achieve a truly tight system, can be heated in even the coldest climates for as little as $100 per year.[73] Air-to-air heat exchangers are advised for super insulated homes to provide proper ventilation. This technology is readily available.[74]

Guidelines for energy-efficient homes in Kentucky, distributed by the Kentucky Division of Energy, suggest insulation appropriate for the 4,000 - 5,000 range in heating degree day totals, double-glazed windows, longer east-west ridge to optimize solar benefits, air-vapor barriers on the exterior walls and efficient, modern heating and cooling systems. Homes built to these standards, while not in the super-insulated category, can still save sizable amounts of fuel and cooling costs. The range of heating cost versus conventional housing suggest a 50 to 75 percent savings. Cooling can be obtained in these houses for an annual cost of as little as $100 per 2,000 square feet of living space.[75]

Solar homes are not prevalent in Kentucky, but homes constructed with the energy-efficient design features typical of solar homes can be constructed here. The benefits derived through encouraging solar based construction in the Commonwealth could be significant in time if undertaken with some planning, support and determination.

4.2.2 Gas-fired home hot water heaters

The same factors discussed above for electric hot water heaters would apply as well to gas-fired systems. These are maintenance, lower operating temperatures and the repair of system leaks. In addition, gas-fired hot water heaters and gas-fired furnace systems offer the possibility of optimizing the flow and availability of combustion air.

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[73] Corbett, R., Hansen, W. and Jon Sesso, *Super Insulation: A Housing Trend for the 1980's*, National Center for Appropriate Technology (NCAT), Butte, MT., pp 1 (1984).
[74] *Heat Recovery Ventilation for Housing: Air-to-Air Heat Exchangers,* NCAT-DOE/CE15095-9, (1984).
[75] *Energy Efficient Home Plans,* Kentucky Energy Cabinet, Division of Alternate Energy, Lexington, KY., (1987). [The Kentucky Energy Cabinet is now designated as the Department for Natural Resources, Division of Energy, 663 Teton Trail, Frankfort, Kentucky.]

Optimization of the combustion process also serves to make the home safer by reducing the chance that hazardous combustion products will accumulate.

Savings from combustion air optimization are generally site-specific. Reduction in fuel demand on the order of 8 to 10 percent have been recorded for the region using one of several methods.[76]

4.2.3 Gas-fired cooking stoves.

A number of ways to save energy in cooking apply to electric as well as gas-fired systems. Most of these are self-evident, such as matching the pan and heating element size
and heating water in closed rather than open containers. General cleanliness and maintenance are also important.

Gas stoves and ovens are also available now with electronic ignition systems in the place of pilot lights. These can reduce cooking gas use by as much as 40 to 50 percent for top burners.[77]

4.2.4 Policy initiatives for reducing residential demand for fuels.

Policy initiatives designed to promote improved efficiency in use of residential electricity apply to some degree to conserving fuel use. Insulation benefits both needs particularly. Others have a similar synergistic effect. For example, a super-insulated house would by design require optimization of combustion air for health purposes. It is probable, given these sorts of realities and relationships, that one set of well chosen initiatives may well be found to serve all causes in this area.

4.2.4.1 Policy initiatives to conserve residential heating fuels through education

Well designed educational programs are probably among the more cost-effective means of achieving the goal of significantly reducing fuel use. Such programs, if

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[76] *Introducing Supplemental Combustion Air to Gas Fired Home Appliances,* NCAT-DOE/CE/15095-7, pp. 26, (1983).
[77] *Ibid,* DOE/CE-0231, pp. 12.

properly funded and if supported by a wide range of government agencies, could be very beneficial.

These programs would need to apply to a large segment of the population ranging from urban to rural settings. The goal of the program would be to develop a populace that would support retrofit of older homes, and support payment of the additional first cost of new homes with better designs. Properly designed highly efficient new homes can be built at an incremental cost of zero to 4 percent compared to conventional construction methods.

4.2.4.2 Policy initiatives to conserve residential heating fuels through tax incentives

Tax incentives, for such as new home construction and for purchase of energy-efficient appliances, have a good deal to offer for conserving residential fuels. New homes with new appliances use only a fraction of the energy of older housing. Replacement of older housing, or extensive retrofit, is possibly the best option available in this sector.

4.2.4.3 Initiatives to conserve residential fuels through changes in building codes

The population of Kentucky is projected to grow by as much as 15 percent through 2020, primarily along the major highway corridors connecting Lexington, Cincinnati, Louisville and Bowling Green. A policy initiative designed to improve housing built for this population would be of obvious benefit for all of the reasons cited above.

Building codes that include energy end-use efficiency requirements can be one of the most cost-effective ways to achieve long-lasting efficiency improvements, but only if the codes are widely observed and enforced. Policies and programs that extend to the application of building energy codes across the Commonwealth and provide training and technical assistance for code officials could have major impacts on residential energy use in the long run.

4.2.4.4 Potential savings in the use of residential fuels

The baseline scenario assumes a reduction in use of residential fuels by 10 percent in the absence of any additional policy initiatives. The application of educational

programs, tax incentives and modification and enforcement of building codes will no doubt improve on this. Ultimately, such incentives could provide at least a doubling of the 10 percent reduction figure, if not more. Such a reduction would provide a savings of 700,000 tons CO_2 per year.

4.3 Methods for reducing the demand for electricity in the commercial sector

The commercial sector includes a wide range of establishments ranging from multi-million dollar holding and insurance companies to small, family-owned retail businesses. Areas in which electricity can be quickly and conveniently saved in these establishments may be found in office design strategies, building construction (if a new facility) and through the purchase of energy efficient appliances.

Municipalities are also included in the commercial sector. These represent a significant portion of the demand, and since they are centrally controlled by well identified governmental bodies, they offer a significant opportunity for policy-driven initiatives.

4.4 Methods for enhancing the efficiency for fuel use in the commercial sector

Fuel use in the commercial sector is mostly for the purpose of providing building heat. Lesser amounts are used for cooking fuels and for hot water heaters. Thus, as in the case for conservation of electricity, building construction and fundamental techniques for conservation apply. In this case, fuel switching may also apply where coal is still in use.

As mentioned above, municipalities are included in this sector. Fleet operations are a significant component. Because of the location of controlling systems, it may be easier to develop strategies for fleet operations than for vehicles in general.

4.5 Methods for reducing light industrial demand for electricity

Light industries include smaller manufacturing facilities. These represent a possible major growth sector for the Commonwealth's future and thus offer a unique opportunity for development of mitigation strategies. Most new plants of this type are expected to locate along the major highway corridors already noted in Figures 2. Strategies for conserving electricity, beyond those already noted as common to all

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sectors, will likely be unique to each plant. Here, as in most industrial settings, it is likely that individual energy audits will be necessary.

4.6 Methods for enhancing the efficiency of fuel use in light industries

Fuel use in light industries will be primarily for building heat. Since building design may well be unique to the manufacturing operation, analysis may also depend on individual energy audits.

4.7 Methods for reducing the demand for electricity in heavy industry

Heavy and light industry combined easily command 50 percent of the electricity used in the Commonwealth of Kentucky. Here again, incentives and strategies leading to energy management audits and action plans may prove beneficial.

4.8 Methods for enhancing the efficiency of fuel use in heavy industry

Fuels are used in heavy industries for a variety of purposes in addition to heating buildings. The same techniques for conservation mentioned above apply here, as do strategies encouraging more efficient use.

Heavy and light industries also must meet the requirements of the Clean Air Act Title V permitting. This requirement leads to energy and materials management audits collectively bringing about some reductions in emissions. Strategies encouraging these policies may well prove beneficial, particularly in reducing VOC emissions.

The heavy industrial sector, which includes the region's utilities, is an important group for which to develop strategies. These strategies include a wide range of incentives, including those in support of fuel switching, improvement in energy end-use efficiencies and CO_2 removal and scrubbing systems, to name a few.

4.9 Methods for enhancing the efficiency of liquid fuel use in transportation

The strategies available to reduce transportation fuel use may be divided into two broad categories: strategies leading to increased ridership (car pools, company bus transportation and mass transit systems) and strategies that encourage more efficient engine operation, including those in support of combined fuel cycles (fuel cells, electrically driven and alternate fuel internal combustion engines). This quickly becomes

a complex area of study involving the interactions between industrial and commercial establishments and between government and the private citizen. For example, tax incentives favoring companies that encourage car pools would immediately involve all of these entities.

4.10 Methods for reducing transportation emissions per unit of fuel used

Consideration is given here to incentives that lead to more efficient operation of family automobiles and fleet vehicles subject to emissions testing programs. These programs are directed at reducing photochemical smog in populated areas (and thus ozone), but have the secondary effect of reducing greenhouse gases as well. Here fuel switching and development of alternate fuels may become important, as will the marketing of all-electric vehicles. It is interesting to note that as of the time of this report, there are no recharging stations located in Kentucky for residential electric vehicles.

4.11 Methods for reducing fugitive CFC emissions

Developments in production of alternate refrigeration cycles are expected to significantly alter the way in which CFC-like compounds are used in the future. Incentives to purchase more efficient systems and to utilize more fresh foods could prove important.

Building codes and energy conservation plans that result in less use of air-conditioning will also benefit CFC reduction, as will elimination of some industrial practices (*i.e.,*foam blowing).

4.12 Methods for reducing emissions of methane due to coal mining

The business of methane capture and utilization presents some fairly fractious issues to overcome. The main issues are ownership and availability—key questions for which it seems we seldom have answers.[78] Ownership is a particularly difficult issue in

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[78] Personal communication from Stephen T. Blackburn, Operations Manager and Attorney for Black Warrior Methane Corporation, 13849 Highway 216, Brookwood, AL 35444. Mr. Blackburn is both an attorney and a registered engineer.

that it involves conflicts over mineral rights, surface rights, and rights, both supposed and real, to gas sources without definite boundaries. As a result, coal-bed resources are not well developed in Kentucky. However, it is highly probable that reserves do exist in Kentucky's coal fields sufficient to make coal-bed methane capture a suitable mitigation strategy to develop.

Oil and gas production associated with coal beds has not been developed in the Appalachian Basin as well as in other locations of the U. S., or as well as the coal resources themselves. As a result, some large measure of this valuable resource is emitted to the atmosphere during the normal course of mining.

We have less readily available information on potential gas (and oil) bearing coal formations. Fortunately, this situation is soon to be remedied through efforts of the West Virginia University Research Corporation's *Appalachian Gas Atlas Project - A Data Base for Independent Producers.*[79] It should thus be anticipated that strategies may in time be developed to benefit this area.

4.13 Methods for reducing emissions due to bulk chemical manufacture

Some industries producing bulk chemicals with significant emissions of greenhouse gases were identified during Phase I of this study. These were for the manufacture of lime, processing of aluminum and the production of CFCs. In addition, the manufacture of a number of other chemicals identified as possible greenhouse gases was cataloged on a county level.

Of these, the manufacture of CFCs proved to be the most significant as a result of HCFC-22 byproduct release. The newly amended Clean Air Act and Title V permitting can be expected to assist in reducing emissions from this type of source. In addition, some of the major producers are already involved in developing greenhouse gas reduction action plans under a municipal program based in Louisville and Jefferson County.

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[79] West Virginia University Research Corporation, *Appalachian Gas Atlas Project - A Data Base for Independent Producers*, Project Contacts: (1) D. G. Patchen, WKU Research Corporation, Morgantown, WV and (2) H. D. Shoemaker, DOE, Morgantown Energy Technology Center: hhtp://www.metc.doe.gov/projfact/fuels/gasatlas.html.

4.14 Methods for reducing emissions due to fertilizer application

Reductions in the rate of chemical application, including that for fertilizer, have been the subject of considerable research over the past decade. Some of this work has found application in the field and some farming techniques are now being used which do require less fertilizer.

Replacement of tobacco as a cash crop may also have a significant effect on agricultural emissions if new crops can be found that require less chemical treatment. This is probable given that tobacco does require a higher rate of fertilizer application than most other farm crops.

4.15 Methods for reducing emissions from manure management

Manure management systems, especially those for large industrial farms, offer some opportunity for reductions in methane emissions. Application of some aspect of the Kentucky Pollution Discharge Elimination System permitting system (KPDES) may be more important in this area. The Commonwealth has held primacy for enforcement in the this area since the early 1980's. At this time a well developed KPDES permitting program is in place which is now effectively managed by the Division of Water.

Policy initiatives and incentives designed for stream recovery may be just as effective in reducing emissions from manure management systems as any that can be found. One possibility would be to support construction and operation of aerobic waste treatment systems or, if anaerobic, for the capture of the methane produced. Emergency regulations for swine feeding operations were been signed into law for the Commonwealth of Kentucky on April 17, 1998. A public hearing on the Notice of Intent to promulgate the ordinary regulations has been set for June 25, 1998 in Frankfort, Kentucky. It is presumed that these regulations will be put into operation soon after, and that steam systems and air quality will benefit as a result.[80]

US EPA also sponsors a ruminant livestock methane program. This program was created in 1993 and its purpose is to encourage application of inexpensive ways of

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[80] More details on the emergency swine regulations may be obtained from
http://water.nr.state.ky.us/dow/swineregs.htm.

reducing livestock methane emissions through feeding, grazing strategies, dieting methods, animal health, breeding and genetics.[81]

4.16 Methods for reducing emissions from landfills

Design and operational parameters for new landfills can be set to reduce methane emissions. Older systems, especially those without definite boundaries and known histories, offer little opportunity for techniques to reduce methane emissions. In addition, municipal recycling systems offer an opportunity to reduce the quantity of material being landfilled.

Strategies that identify major metropolitan areas may be expected to be of benefit here. These areas are expected to develop further in the future, particularly along major highway corridors. This may in time require the development of new waste treatment sites and, if so, the opportunity exists to develop methane capture or flare systems for these systems before they go into operation.

It is important to note here the State is a participant in the voluntary Landfill Methane Outreach program supported by US EPA. This program involves the Natural Resources and Environmental Protection Cabinet and currently enrolls the Divisions of Energy, Waste Management and Air Quality. Incentives developed in response to this ongoing program would be an obvious place to start.

4.17 Methods for reducing emissions from sewer systems

Sewer systems emit volatile organic hydrocarbons, some of which are greenhouse gases, and methane. Improvement in plant operation and solids handling techniques can reduce this problem. Here again, it is the design of newer plants that needs to be considered.

Replacement of septic fields, a persistent problem in the Commonwealth of Kentucky, would also be of benefit. Policies and incentives for formation of wastewater treatment districts in more of the state's 120 counties would be of benefit here. At present only a fraction of the state's counties have these agencies. As a consequence, large segments of the population live without access to a wastewater plant. This in turn

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[81] More details on the US EPA ruminant livestock methane program may be obtained from

requires the use of septic fields, a problem for public health, stream viability and greenhouse gas emissions in the form of methane.

4.18 Methods for enhancing renewable energy conversion systems

Renewable energy conversion systems (solar and hydroelectric) have some role to play in the reduction of greenhouse gases. It is doubtful that hydroelectric power systems can be increased in the state, although some policy incentives may be found to support those already in existence. Solar systems, however, do offer some opportunity. Policy initiatives supporting the buy-back of excess electricity generated by solar electric systems could be of significant benefit in encouraging the development of solar power facilities in all sectors.

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http://www.epa.gov./earth1r6/6xa/vplivest.htm.

5. POTENTIAL FOR GHG EMISSION REDUCTIONS THROUGH EXISTING ENERGY CONSERVATION PROGRAMS

A number of federal, state, and local programs have come into being in recent years that should be considered as components of the Kentucky mitigation strategies study. These include national and state pollution prevention programs, initiatives designed to improve the efficiency of energy use, combined industry-city resource conservation and pollution prevention programs, programs designed to enhance capture of landfill gases, and others. The major programs currently operative in Kentucky are outlined below.

5.1 Kentucky Division of Energy

The Kentucky Division of Energy (KDOE), a small office within the Natural Resources and Environmental Protection Cabinet, has been promoting improved energy end-use efficiency and alternate energy sources since the mid-1970s. The eleven-person division administers ongoing energy end-use efficiency programs involving Kentucky's residential, commercial, industrial, and transportation sectors. In addition, it is the Kentucky agency that had the lead in administering Phases I and II of the Kentucky Greenhouse Gas Project under a grant from the US EPA. The following subsections describe KDOE's ongoing programs and in part has been quoted directly from KDOE materials providing details of the agency's current activities.[82],[83]

5.1.1 Institutional Conservation Program (ICP)

KDOE has worked over the past twenty years to administer a grant program using federal and state funds to enable hundreds of Kentucky schools and hospitals to make energy retrofits. ICP was initiated by Congress in November of 1978 for the purpose of

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[82] More information about KDOE activities can be obtained from: Kentucky Division of Energy, 663 Teton Trail, Frankort, KY 40601, (502) 564-7192.

[83] Information detailing the KDOE activities were provided by Mr. Geoff Young, Assistant Director of KDOE and manager of the Division's Alternate Energy Program. For more information contact the Natural Resources and Environmental Protection Cabinet, Division of Energy, 663 Teton Trail, Frankfort, KY 40601,1-502-564-7192; or in Kentucky, 1-800-282-0868.

providing matching grant funds to public and private nonprofit schools and hospitals for Energy Audits (EA), Technical Assistance (TA) and Energy Conservation Measures (ECM). As of 1992 EA's had been completed in 1,812 buildings. This comprised 47 percent of the 3,841 eligible buildings. Of these, 1,683 were school buildings and 129 were hospitals. Another 718 schools have received TA benefits along with 65 hospitals. ECMs have been completed on 558 eligible schools and hospitals.[84]

Actual savings in energy usage for completed projects range from 22 to 53 percent with an average of 32 percent.[85] The average reduction in energy expense is 25 percent. Federal funding for the program, which was always less than the amount needed, is now ending. There is a possibility that financing for energy end-use efficiency measures will be provided to school systems and hospitals in the future by energy services companies (ESCOs).[86]

5.1.2 Energy end-use efficiency in Government Buildings

KDOE and the Kentucky Finance and Administration Cabinet are cooperating in a relatively recent initiative to boost efficiency in the approximately 50 million square feet of space owned by state government, as well as to provide training to state building operators in efficient operation and maintenance activities. Another initiatives to help agencies enter into performance contracts with energy service companies to provide third party financing for energy end-use efficiency measures.

It should be noted that legislation has previously been passed in support of enabling the more efficient use of energy resources in Kentucky State government buildings. At present however, funds have not been allotted to carry out this mandate.

5.1.3 Students Weatherization and Training (SWAT Jr.) Program

KDOE works with school systems throughout Kentucky to train teams of high school students and a faculty adviser to perform energy audits in their school and propose

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[84] Noland, James H., ICP Program Manager; *Energy Savings Documentation in Support of the Energy Conservation in State Owned Buildings,* Natural Resources and Environmental Protection Cabinet, Department for Natural Resources, Division of Energy, 663 Teton Trail, Frankfort, KY 40602, March 18, 1992; p. 10-18.
[85] Ibid., Noland, James H., p. 19-24.
[86] Ibid., Noland, James H., p. 13.

energy end-use efficiency measures to school administrators. The program has been well received for its educational value as well as for the energy cost savings that can be put to use for other school activities.

5.1.4 Demand Side Management (DSM)

For the past four years, KDOE has been involved with collaborative efforts at three investor-owned utility companies in Kentucky: Louisville Gas and Electric Company (LG&E), American Electric Power, and Cinergy. In all three cases, representatives of customer groups have engaged in joint planning efforts with the utility and KDOE to institute programs to help the utility's customers save energy and reduce their energy expenses. In the commercial sector, most of the DSM programs to date have focused on delivering energy audits but attention is increasingly focusing on methods to increase the implementation of energy saving measures. Such methods include assistance with financing, technical assistance, and, under certain conditions, cash rebates.

5.1.5 Alternate Energy Program

KDOE provides technical information to businesses and individuals in Kentucky that want to make cost-effective use of biomass, solar, and other renewable energy sources. The experiences gained over the years through a series of biomass and solar energy demonstration projects will be made available to Rebuild America partners.

5.1.6 Other Energy Programs

KDOE is involved in a number of other small-scale efforts to promote the efficient use of energy. These include the following:

(1) Supporting energy education in schools;

(2) Helping firms apply for federal funds to demonstrate energy-efficient and alternate energy technologies;

(3) Facilitating the collection and recycling of used motor oil, saving energy at the refinery;

(4) Assisting the Kentucky Division of Building Codes Enforcement in ensuring that energy codes are met to the greatest extent possible and;

(5) Helping the Kentucky Transportation Department publicize a system of carpools and vanpools for commuters.

5.2 U. S. Department of Energy Industrial Assessment Centers

The U. S. Department of Energy supports 30 industrial assessment centers located strategically throughout the United States. The principal grant holder for the Eastern Division of the U. S. is the Office of Industrial Productivity and Energy Assessment located at Rutgers, The State University of New Jersey, Piscataway, NJ 08855-1179 (732) 445-5540; oipa@camp.rutgers.edu. The Industrial Assessment Center (IAC) for the Kentucky region is located at the University of Louisville and may be reached at (502) 852-7860; 01jcwatt@ulkyvm.louisville.edu. This center was established in January 1994.

IAC centers, as in the case of the one with Kentucky coverage, are located at regional universities. These institutions provide faculty and students primarily from engineering schools, for site visits and energy audit assessments. The Kentucky IAC is associated with the Department of Chemical Engineering at the University of Louisville. IAC centers focus their attention on small to medium sized manufacturing facilities in the SICC code range 20-39. The U of L IAC covers western and central Kentucky and a narrow corridor extending to Ashland; the U. of Dayton IAC covers northern Kentucky; and the IAC at the U. of Tennessee in Knoxville covers southeastern Kentucky.

"Small to medium sized" refers to those companies with gross annual sales below $75 million, with fewer than 500 employees, with annual utility bills more than $75,000 but less than $1.75 million, and without in-house professional staff to perform assessments. Slightly more than half of the industries in the United States appear to fall in this category.[87]   Ideally, the companies to benefit will be found within 150 miles of the host campus.

University faculty-student teams conduct one-day site visits to initiate an energy audit and assessment. A report is filed within 60 days of the visit detailing findings and providing recommendations. The process is followed up by a phone call six to nine

months later. Nationwide, the average annual cost savings realized per IAC assessment would be $55,000 if the recommendations suggested were implemented.

5.3 Kentucky Pollution Prevention Center (KPPC)

Pollution prevention (P2) has been a focus of the Kentucky General Assembly and the Executive Branch for a number of years. The current program is the outgrowth of work initiated at the University of Louisville in the early 1980's.[88] The program has since grown to funding levels now approaching $900,000 per year and is expected to expand further.[89] The KPPC has a staff of ten and is managed by an eleven member Board of Directors.

KPPC was enabled by an act of the Kentucky General Assembly to provide advice to clients about waste-stream minimization. Waste-streams include those of hazardous wastes, solid wastes, and emissions to air and water. The KPPC also provides environmental training and has access to a new range of modern laboratories in which applied research can be conducted in support of pollution prevention studies for interested clients. The KPPC offers on-site technical assistance, P2 training and research. In 1996 the KPPC technical staff completed 45 assessments and scheduled another 15. Training programs attended by 2,900 employees industry and government were also conducted along with a wide range of teleconferences. The KPPC downlinked 27

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[87] 1994 U.S. Census statistics as cited in Hall, Rebecca Ann ; *Assessment of Metal Roof and Wall Insulation for Industrial Energy Conservation,* Master of Engineering Thesis, Department of Mechanical Engineering, December 1997, p.4.

[88] The program was founded by Dr. Marvin Fleischman (U of L Chemical Engineering) in the early 1980s. The KPPC Board is currently chaired by Mr. Ray Dailey of Westvaco Corporation. The current executive director of KPPC is Mr. Cam Metcalf. Information concerning the KPPC may be obtained from: *Kentucky Pollution Prevention Center,* University of Louisville, New Academic Building, Belknap Campus, Louisville, KY 40292; (800) 334-8635; web site: http://www.louisville.edu/org/kppc.

[89] Funding levels for 1996-1997 were as follows:
Hazardous Waste Assessment Fund $388,900
University General Fund $ 40,630
Pollution Prevention Incentives Grant $ 65,000
Environmental Justice Through P2 Grant $270,644
NIST P2T2 Contract $ 20,000
Solid Waste Initiatives in Kentucky Grant $ 88,500
Total $873,674
!996-1997 Annual Report; Kentucky Pollution Prevention Center, University of Louisville, New Academic Building, Belknap Campus, Louisville, KY 40292; (800) 334-8635; web site: http://www.louisville.edu/org/kppc.

teleconferences in 1996-1997 for Kentucky industries. In addition, the KPPC initiated its first national satellite teleconference with the help of the University of Louisville's Television Service. A total of 150 hospitals and organizations viewed the program in 16 states. The center also provides extensive information resources and operates a web site at address http://www.louuisville.edu/org/KPPC.

The KPPC maintains an active research program for industry, and consistently seeks additional outside support from a variety of granting agencies. Funding from these resources totaled $444,144 for the 1996-1997 period. The principal granting agency supporting the KPPC has been U.S. EPA. Grants are in support of training, technical assistance, development of pollution prevention incentives and the search for environmental justice in West Louisville.

The KPPC, in response to local and national needs, will initiate work in the area of greenhouse gas reduction in the late winter of 1998. Four half-day training workshops will be offered for Louisville manufacturers showing them how to turn improved efficiency in energy use into profit and increased productivity. Part of the advice and technical assistance offered will be generic and part will be industry-specific. The workshops are offered in association with Climate Wise, which is a joint EPA-Department of Energy program.

Details sufficient to assess the tonnage of greenhouse gas removed so far as a result KPPC activities are not available. Tracking in the future of energy savings and waste reduction in areas where emissions are curtailed will likely be kept in the future for planning and assessment of progress in this important area. The KPPC does adjust to the needs of the times and is clearly doing so in this instance.

5.4 Climate Wise

Climate Wise is a government-industry partnership designed to "turn energy efficiency and environmental performance into a corporate asset."[90] The partnership is jointly sponsored by U.S. DOE and U.S. EPA. Participants include major pharmaceutical firms, aircraft manufacturers, breweries, and printers.

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[90] *Climate Wisdom, An Update of Events, Actions, and Efforts of the Climate Wise Program*, Spring-Summer 1997, p.1

Member companies have been involved with improving equipment and operating processes within the company; utilizing more appropriate fuel types for various applications; creating new and more efficient products; and, participating with other similar pollution reduction and energy end-use efficiency programs.[91] "By the year 2000, Climate Wise companies will annually save more then $300 million and reduce more than 20 million metric tons of carbon dioxide".

Climate Wise has recently begun a toll-free technical assistance *Wise Line* (1-800-459-9473). Among the services offered on the *Wise Line* is help with reporting greenhouse gas emissions and emission reductions under the Voluntary Reporting of Greenhouse Gases Program (Climate Wise Action Plan Form EIA-1605).

During Summer of 1997, Climate Wise released *Wise Rules for Industrial Efficiency*. The document includes guidelines for "estimating the energy, costs and greenhouse gas emissions impacts…Focusing primarily on boilers, steam systems, and compressed air systems, the *Wise Rules* are a compilation of best available industrial energy efficiency data available".

Louisville, the state's largest city, has recently joined the Climate Wise Team. The program management is currently recruiting new industrial and government agency partners by showing how energy efficiency translates into pollution prevention, increased productivity and cost reduction.

5.5 Landfill gas recovery programs

The Kentucky Natural Resources and Environmental Protection Cabinet has been designated as a state ally in the U.S. EPA's Landfill Methane Outreach Program (LMOP). The program was developed to encourage the use of landfill gas (methane) as an energy resource. This is accomplished by minimizing informational and regulatory barriers, and by promoting the environmental and economical benefits of using landfill gas as an energy source. Twenty landfills in Kentucky are estimated by EPA to have the potential to support economically viable gas-to-energy projects. Together these offer a resource of 47.7 mmcf/day of methane with a generation potential of 76.5 MW. [92]

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[91] DOE/EE-0071 EPA 230-K-95-003, April 1997.
[92] Ibid., candidate landfill profiles, leading page.

Electricity generation, space heating and cooling, industrial processing, and vehicular fuel are among the uses for landfill gas. The generating capacity of landfill gas systems range between 0.5 and 4 MW electric.[93]

Estimates of the equivalent of CO_2 emission reduction to come from these operations if all twenty were developed with capture and usage systems vary depending on which EPA document is cited. A recent report entitled *Opportunities for Landfill Gas Energy Recovery in Kentucky* (EPA 430-B-97-033) provided data for an estimate of the quantity of landfill gas (LFG) being emitted from Kentucky landfills in 1998.[94] The report estimates the amount of methane that could be harvested from the 20 landfills which are considered to have the greatest potential for LFG-to-energy projects. In addition, there are estimates of the quantity of CO_2 emissions that would be offset by the displacement of coal and oil fuel through the recovery and use of LFG.

There are presently no LFG-to-energy systems operating in Kentucky, although LFG is being flared at two landfills, one of which is the state's largest.[95] The sum of methane potentially available in 1997 from the 20 candidate landfills identified by US EPA is 4.9 million tons of equivalent CO_2. Subtracting the quantity of methane that is being flared yields 3.6 million tons of equivalent CO_2. The emissions figure estimated by Spencer for all landfills in the 1990 Kentucky Inventory was 2,773,997 tons per year.[96]

5.6 US EPA Green Lights and Energy Star Buildings Programs

Green Lights is an EPA sponsored program which encourages the use of energy-efficient lighting. The program descriptive documents indicate that participants can realize average rates of return on their initial investment of 40 percent or more. They can reduce their lighting electricity bill by more than half while maintaining and often improving lighting quality.[97] Green Lights includes over 2,400 participants nation-wide

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[93] Ibid., p. 1-3.
[94] Ibid., candidate landfill profiles, leading page.
[95] *Opportunities for Landfill Gas Recovery in Kentucky,* US EPA 430-B-97-033, September 1997, p. 1-2.
[96] Spencer, H. T., *Kentucky Greenhouse Gas Inventory: Estimated Emissions and Sinks for the Year 1990,* University of Louisville, Speed Scientific School under contract with The Kentucky Natural Resources and Environmental Protection Cabinet using funds provided by the US EPA, Office of Policy, Planning and Evaluation, Federal Assistance No. CX822849-01-0 (1996).
[97] EPA 430-F-97-042.

including corporations, federal, state, and local government agencies, health care facilities, universities, hotels and restaurants.

EPA's Energy Star Buildings Program was created to "enable building owners to achieve additional energy savings while lowering capital expenditures."[98] The program, like Green Lights, is strictly voluntary and targets those who operate and maintain commercial and industrial buildings. Those who do participate lower energy costs by promoting energy efficiency. EPA estimates that Energy Star Buildings participants can reduce energy consumption by 40 percent, and can lower electricity bills by 35 percent. Return from these activities in terms of reduction of CO_2 emissions however, is predicated on subsequent and corresponding reduction in electricity production. Nothing is gained in terms of CO_2 emission reductions if the electricity saved by one end-user is simply picked up and used by another, unless the means of electricity generation itself is likewise made more efficient.

Data was presented in Table 5 indicating the split in end-use of electricity among the principal economic sectors. These divisions were: Industrial -- 47 %; Commercial -- 17%; Residential -- 24%; Transportation -- 0%; Transmission losses -- 10%; and Export -- 3%. The CO_2 emissions associated with electricity generation for in the 1990 study was 76,449,370 tons per year, which constitutes 37 percent of the gross emissions for Kentucky in that year.[99] Green Lights and the Energy Stars Buildings program, if brought to their maximum potential and if the savings were translated into a 35 percent reduction in actual electricity production, could over a period of years reduce the 76,449,370 figure by a factor of [0.35 x (0.47 + 0.17)] x 76,449,370 = 17,124,659 tons per year. This would be a significant reduction if, once again, it is assumed that the electricity saved is not sold to other end-users.

5.7 Coalition for Environmentally Responsible Economics (CERES)

CERES is a coalition of "leading social investors, environmental groups, religious organizations, public pension trustees and public interest groups" that endorses a ten principle code of environmental ethics. The principles include: protection of the

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[98] EPA 430-F-97-042.

biosphere, sustainable use of natural resources, reduction and disposal of wastes, energy conservation, risk reduction, safe products and services, environmental restoration, informing the public, management commitment, and annual audits and reports. At its founding in 1989, a long-term agenda was adopted "to focus on various ways investors could help implement environmentally and financially sound investment policies." Coalition members include over 10 million people and represent over $150 billion in invested assets.[100]

The Louisville Jefferson County Metropolitan Sewer District has been very active in the Louisville community in applying the CERES principles to its operations.

5.8 International Council for Local Environmental Initiatives (ICLEI)

ICLEI is an international association of local governments dedicated to the solution of environmental problems through local action. Among the services and products offered by this group are the following:

a) Consultant Network - a world-wide network of consultants is available.

b) Case Studies Series - summaries of innovative municipal practices with highlights of successful environmental management highlights.

c) ICLEI Newsletter - a report on organizational activities and plans.

d) Special Publications - papers and project reports on specific areas of policy concern.

e) Referral Services - a network of "municipal professionals, experts, corporations, and development agency staff" who are ready to lend their expertise to problem solutions.

f) Computer Conferencing - LEICOMM (Local Environmental Initiatives Communications Systems) provides referral and other services via computer communications.

g) International Training Center - provides curriculum development and world-wide training.

One of ICLEI's successful ventures is the Cities for Climate Protection Campaign (CCPC). Based upon the 1989 greenhouse gas reduction program in Toronto - a pledge

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[99] The 76,449,370 figure is for CO_2 emissions in Kentucky in 1990 due to combustion of bitumunious coal by the Commonwealth's utilities.

by that city to reduce greenhouse gas emissions in the city by 20% below 1988 levels by the year 2005 - ICLEI initiated the Campaign. "The Campaign enlists local governments to develop targets, timelines and implementation strategies for climate protection."[101] By late 1997, 48 U.S. cities and counties representing 24.7 million people and 7% of U.S. greenhouse gas emissions were participating in CCPC.

Each local government commits to climate protection action, sets a greenhouse gas reduction target, and develops a local action plan to meet that target. Recommended steps to meet that target include:

a) base year emissions analysis and forecast;

b) greenhouse gas emissions reduction target established;

c) local action plan or emission strategy created;

d) implementation of the plan by local government.

ICLEI has recently initiated a program in the Louisville Metropolitan area through a grant assigned to the City of Louisville. Funding through this source and others has helped support the Louisville Conservation Council (LRCC) in its effort to coordinate efforts of the city government, Jefferson County government, the Kentucky Pollution Prevention Center (KPPC), the Metropolitan Sewer District, the Louisville Gas and Electric Company (LG&E), and several local industries including DuPont which, for example, has pledged a 40 percent reduction in its energy consumption.

5.9 Programs in the Transportation Sector

Residents of the Commonwealth of Kentucky in 1990 registered 4,667,384 vehicles, collectively 1.2 vehicles for every man, woman and child in the State. These included commercial vehicles, passenger cars, farm trucks, and motorcycles. The greenhouse gas contribution from these vehicles estimated in the 1990 inventory was 28,982,812 tons of CO_2 per year which comprised 14 percent of the total emissions cataloged.

The Commonwealth does not have an organized program to specifically deal with fuel conservation in the transportation sector. A vehicles emission testing program

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[100] *Ceres Principles*, informational brochure, January 1, 1997.

(VET) has been in operation in Jefferson County since 1984. This program is now well advanced and requires that all passenger cars, light trucks (private and commercial), and fleet vehicles be tested yearly for hydrocarbon and carbon monoxide emissions. Vehicles are also inspected at the time of testing to insure that pollution prevention devices are in place and functional. Vapor control at the pump was introduced through the program in 1995. The Louisville program was put in place to help reduce photochemical smog levels over the city of Louisville. The VET program was initiated in response to the Louisville and Jefferson County community being declared "non-attainment" for ozone, a designation which grew to included 15 Kentucky counties by 1991. Nine of these were removed from the list in 1995 but six remain. They are Boone, Kenton, and Campbell counties in northern Kentucky; Jefferson County and portions of Bullitt and Oldham counties. The state has subsequently submitted an ozone reduction plan to US EPA which includes VET programs, reformulated gasoline (RFG), and vapor recovery systems. As of 1995, RFG was required at pumps in Boone, Campbell, Kenton, and Jefferson Counties, and in parts of Bullitt and Oldham Counties. A VET program will be implemented for Boone, Kenton, and Campbell Counties.[102]

A number of commercial and industrial fleet operations have undertaken fuel conservation measures on their own, as have some government agencies. The United Parcel Service in Louisville and the Louisville Metropolitan Sewer District have converted a number of vehicles from gasoline and diesel to CNG (compressed natural gas). Over the past three years, the Kentucky Division of Fleet Management, which looks after the State's motor pool, has purchased 250 vehicles capable of operating on any mixture of gasoline and ethanol up to 85 percent ethanol. It is anticipated that another 140 vehicles will be purchased in the near future and the Division is working with the Kentucky Corn Growers Association to establish ethanol refueling facilities in the State.[103]

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[101] U.S. Communities Acting to Protect the Climate - A Report on the Achievements of ICLEI's Cities for Climate Protection - U.S., November 1997 p. 2.

[102] More details and updates on the topic of Kentucky's on-going efforts to achieve ozone attainment can be found on the Division of Air Quality web page
[http://www.state.ky.us/agencies/nrepc/dep/daq/outreach/smog.html

[103] *Conservation Update*, State Energy Programs, January 1997
[http://es.epa.gov/new/contacts/newsltrs/kyupdt/kyupdt.html]

A total of 743,833 vehicles were registered in 1990 in the five counties with VET programs, vapor recovery, and RFG at the pumps. These contributed an estimated 4,606,192 tons of CO_2 in that year, which was 16 percent of the emissions coming from the transportation sector. The degree to which this figure has been reduced through smog reduction programs is not exactly known. However, the EPA target for the region is a 15 percent reduction in ozone generating emissions. If, as seems the case, this is achieved through an improvement in engine efficiency, it seems reasonable to assume that CO_2 emissions will likewise be reduced.

5.10 Kentucky NEED program

A Kentucky chapter of the National Energy Education Development (NEED) Project began operating in 1994 and had gradually increased its level of activity since then. The program provides unbiased information and well-designed curricula about energy issues to students and teachers in trades 5-12. The materials and activities emphasize cooperative learning ("Kids Teaching Kids") and have successfully raised the level of students' understanding about energy. The energy impacts of educational activities such as Project NEED are likely to be long-term in nature and difficult to quantify, but they are nonetheless important.

5.11 Summary of Potential Benefits from Existing Energy Conservation Programs

Although a wide variety of energy efficiency and renewable energy programs currently exists in Kentucky, they are operating at a relatively small scale. Unless the resources devoted to such activities are increased, no additional energy savings are likely to result by the year 2020 beyond those specified in the baseline assumptions (see Section 3.4). In other words, the existing energy-related programs being carried out in Kentucky are estimated to contribute to the projected 10 percent improvement in energy efficiency in the residential, transportation, commercial, and industrial sectors, but are not projected to generate reductions in GHGs if maintained at their current levels. Additional policies and programs would be needed in order to achieve GHG reductions beyond the base case. Policy options designed to go beyond the base case are discussed in Chapters 6 and 7.

6. POLICY OPTIONS FOR MITIGATING GREENHOUSE GAS EMISSIONS

Policy options to reduce the emission of GHGs in Kentucky have been designed to meet two criteria:

(1) The policies proposed for consideration must not be too costly. Indeed, wherever possible, they should be designed to generate net benefits for the Commonwealth's economy.

(2) The policies proposed for consideration must be flexible. It should be possible to implement them on a small scale at first, to expand or intensify them over time, and to adapt them as conditions change or as practical experience is gained.

Many of the policy options that follow are presented first in a relatively modest form and then in a more intensified form. Taken together, the set of "modest" policy options is designed to represent a comprehensive strategy that should not be very difficult or costly to implement, and which is projected to provide a modest reduction in GHG emissions compared to the base case projection. If it is determined that greater GHG reductions are necessary in Kentucky, the more intensive policies may be considered, individually or as a group, as supplements to the initial set of policies.

It is anticipated that mitigation policies with the potential for cost offset have the best chance of working. This has already been shown in studies similar to this one. Helme *et al.*[104], for example, developed an analysis in 1993 focusing on American Electric Power (AEP), one of the region's larger utilities. Their study conclusions were reported as follows:

> This study offers two very significant conclusions: (1) Flexibility will be a key component of any legislative or regulatory efforts to significantly reduce CO_2 levels while minimizing the cost of compliance; and (2) Offsets -- both forest and coal-bed methane recovery -- when coupled with energy efficiency, offer the greatest opportunity for meeting CO_2 reduction levels in a least-cost way.

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[104] Helme, N., Popovich, M. G. and Gille, J., *Cooling the Greenhouse Effect: Options and Costs for Reducing CO_2 Emissions from the American Electric Power Company,* Center for Clean Air Policy, 444 North Capitol Street, Suite 602, Washington , DC 20001, pp. 25 (1993).

One may suggest that these things are, or should be, self evident. However, this has not always been the case. Fixed target mitigation levels were initially the rule, and seemingly at whatever the cost needed to be.[105] What Helme *et al*. have stated in their conclusions is that we have now gone beyond that point. What is needed instead is a weave of self-supportive, flexible strategies. Emission reduction targets are useful in developing these strategies in that they do provide a means of evaluation and comparison, but they should not be considered to be sacrosanct.

The *Iowa Greenhouse Gas Action Plan*, issued in December, 1996, by the Center for Global and Environmental Research and Public Policy at the University of Iowa, presents a set of sixteen "Priority Options" that can be implemented relatively easily, and a more ambitious program of "Maximum Feasible Reductions" that would require greater effort and capital investment and would yield correspondingly greater GHG reductions compared to the base case.

In the course of researching and assessing the policy options presented in this report, it has become clear that no single policy initiative can generate major GHG reductions by itself, *i.e.*, there is no "magic bullet." A successful strategy must combine many small actions taken by participants in all sectors of the Kentucky economy in a way that adds up to make a significant impact.

6.1 Energy Efficiency Initiatives

Because the extraction and use of energy gives rise to such a large fraction of Kentucky's total GHG emissions, many of the policy options proposed for consideration are energy-related.[106] This is generally consistent with the Climate Change Action Plan issued in October, 1993, by the Clinton Administration, which included 24 measures related to improved energy efficiency and nine related to methane recovery in its list of 44 recommended national policy initiatives.

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[105] Nordhaus, W. D., *An Optimal Transition Path for Controlling GHGs,* Science, Volume 258, pp. 1315-1319 (1992).
[106] Spencer, H. T., *Kentucky Greenhouse Gas Inventory: Estimated Emissions and Sinks for the Year 1990,* University of Louisville, Speed Scientific School under contract with The Kentucky Natural Resources and Environmental Protection Cabinet using funds provided by the US EPA, Office of Policy, Planning and Evaluation, Federal Assistance No. CX822849-01-0 (1996), p. 11.

6.1.1 Residential and Commercial Sectors-Improve the Observance and Enforcement of Building Energy Codes

The Alliance to Save Energy, an independent non-profit group based in Washington, DC., has consistently ranked Kentucky's building energy conservation codes among the top in the nation. Indeed, as of March, 1995 this organization ranked Kentucky (A^+), a designation given to only five other states: Minnesota, California, Oregon, Florida and Virginia. These codes are steadily improving across the nation but as of today Kentucky still maintains a ranking of (A). The states at the very top are Minnesota, Ohio, Oregon and Montana.[107]

An AES ranking of A is given to those states with energy codes that meet or exceed the Model Energy Code (MEC). The MEC is published by the Council of American Building Officials (CABO) and is updated regularly by the its code changes committee.[108] FHA and VA financed homes must comply with the MEC. The MEC is becoming the national standard, although at present the AES gives the nation a ranking of (C). Fifteen states are ranked at levels (D) to (F).

Enforcement is key in this state and others. Even Minnesota, which ranks at or near the top in the nation in energy codes, concedes that its code is not adequately enforced. The reasons cited are uneven application of the code between geographic regions, and the lack of technical support at the state level, local staffing and resources, training for enforcement officials, and training for builders, architects, designers and specialty contractors. Each state may experience a different mix of these problems, but the main cause is the same for all; namely, that our energy codes have simply outgrown our ability to enforce them adequately.

Several approaches to this problem are available. However, it would appear prudent in the case of Kentucky to have the legislature empower the Department for Natural Resources, Division of Energy and the Department of Housing, Buildings, and

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[107] The state of Minnesota has developed an excellent energy code which, as of 1998, is a fair match for any in the world. The history of the Minnesota code can be obtained through:[http://www.me3.org/issues/efficiency/eocderpt_ToC.html]. This history cites Kentucky as having been given an A^+ rating by the AES in March, 1995. More recent details on the Alliance to Save Energy may be obtained from:[http://www.oikos.com/esb/42/codesurvey.html#archor1336060].

Construction, Division of Administrative Services with the authority and funding to review the unique circumstances of energy code enforcement in Kentucky. It should be anticipated that this group of professionals will make specific recommendations to the legislature and executive branch for the funding and support needed to carry out our existing energy code mandate.

It is clear that Kentucky has adopted a good set of energy codes for new buildings. However, uneven application of the code between counties, lack of local resources, and lack of technical support and training for code officials, designers, builders and contractors contribute to the problem.

Annual new housing starts comprise approximately one percent of Kentucky's total residential building stock.[109] In the commercial sector, major renovations are added to yield an estimate of 5 percent annual turnover. A statewide program in place by the year 2000, and operated on a modest scale, to inform building code officials, designers and builders about the energy codes and how to meet them in a cost-effective manner could be expected to boost the average efficiency of new buildings by 10 percent compared to the typical new building construction practices prevalent in Kentucky during each year after 2000. Between 2001 and 2020, approximately 18 percent of the stock of residential housing and 64 percent of the commercial space is likely to be newly built or undergo major renovation. The modest program proposed here would therefore improve the efficiency of fuel and electricity use in the residential sector by 1.8 percent and in the commercial sector by 6.4 percent in the year 2020. The net reduction in CO_2 realized from this program would be 1,183,277 tons per year by 2020.

A more aggressive application of this policy would include the following elements:
(1) Expansion of the technical assistance and educational activities described above to reach a greater fraction of the participants in a shorter period of time;

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[108] A number of references can be found to the MEC. Some from DOE provide manuals on how to apply and working check list to follow. A brief description can be obtained from:[http://www.energycodes.org/meccheck/aboutmeccheck.htm].
[109] KDOE "Kentucky Housing Data, unpublished report, July 1995, based on US Census and Dodge Reports.

(2) Establishment of a funding mechanism to provide incentive payments to building designers and contractors to compensate them for the extra time spent designing highly-efficient buildings and major renovations. Financing of energy end-use efficiency measures would be facilitates through a revolving loan fund or third-party energy service companies (ESCOs).

The expected impacts of the program in the year 2020 could be multiplied by a factor of four, for a net reduction of 3,284,318 tons per year.

6.1.2 Residential Sector-Promote Energy-Efficient Mortgages (EEMs) and Institute a Home Energy Rating System (HERS)

Energy-Efficient Mortgages (EEMs) make housing more affordable, allowing home buyers to finance energy end-use efficiency improvements by adding the additional costs to their mortgage. They are currently available from some lenders, but are not very well known. A home energy rating system (HERS) can work with and help popularize EEMs in the housing market.

Several states have implemented HERS programs, and Kentucky is beginning to develop one as well. A process whereby the energy efficiency of homes is given a rating and mortgage terms are adjusted to facilitate efficiency improvements would affect existing homes that are sold as well as new homes. A HERS program implemented on a modest scale could improve energy efficiency in the residential sector by 0.5 percent which would be equivalent to 66,909 tons CO_2 per year by the year 2020.

A major effort to popularize home energy ratings and energy-efficient mortgages, involving all of the interest groups associates with the housing market, could probably boost average residential energy efficiency by 4 percent, which would be equivalent to 509,378 tons CO_2 per year by 2020 over and above the base case projections. (See note below concerning compartive magnitudes of emission reductions for differing degrees of efficiency enhancement.[110]

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[110] The model utilized in the Phase II calculations is non-linear in its response to improvements in efficiency. Thus, as in the HERS program described in Section 6.1.2 improvements of 4 percent in residential efficiency for an aggressive program as compared to 0.5 percent for a modest program, an improvement of eight-fold, the improvement registered in emissions reductions is 509,378 ÷ 66,909 = 7.6. The reasons for this are complex and tend to vary for case to case. However, there are two-features of the program common to all calculations that contribute to non-linearity: (1) the improvements are not simple

6.1.3 Commercial (Institutional) Sector: Expand and Fund the Energy Efficiency In Government Buildings Program

The Division of Energy and the Kentucky Finance and Administration Cabinet are presently cooperating in an initiative to improve energy efficiency in government buildings. This is a recent initiative and has the support of existing legislation. The initiative is far more important than just the savings in tax dollars realized, or the reductions in greenhouse gas emissions. Education of the public on these issues by example is needed in the Commonwealth, and no better way exists than to show the populace how government approaches the business of energy cost reduction for its approximately 50 million square feet of building space.

Other examples of government agencies taking positive steps in improve on the efficiency of energy end-use can be found in the Commonwealth. The Metropolitan Sewer District of Louisville and Jefferson County has adopted the CERES Principles and incorporated them into MSD's Environmental Policy Statement which is compulsory for all employees. MSD, through adoption of the CERES Principles, became partners with US EPA's Green Lights program. Subsequently, the agency hired the Louisville Resource Conservation Council (LRCC) to develop a complete energy audit and to develop a site-by-site work plan for implementation of improvements.[111] The program has been highly successful and has already documented yearly savings on the order of hundreds of thousands of dollars.

The existing legislation calling for energy efficiency in government buildings resembles an un-funded mandate. The most critical need at present is to allow the Department for Facilities Management in the Kentucky Finance and Administration Cabinet to hire approximately three new people to administer the program in state government buildings. The funds to implement efficiency measures can be sought either through future state appropriations or by contracting with energy service companies (ESCOs).

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multiples of un-improved circumstances but instead are treated as additions to the existing basecase improvements percentage and, (2) the impacts of improvements are assumed to start taking effect in 2000 as compared to 1990 for the basecase improvements.

The Kentucky Finance and Administration Cabinet and the Division of Energy are currently implementing the Energy Efficiency in Government Buildings Program on a limited scale, as described in Section 5.1.2. Because state appropriations were not made to fund efficiency improvements, agencies are planning to negotiate shared savings agreements with ESCOs, which would provide up-front capital in exchange for a share of the future energy savings. The efficiency gains projected to result at the current level of effort are reflected in the baseline estimate of GHG emissions. The program could be significantly expanded and the efficiency gains accelerated, however, if it were staffed and funded at the higher level. More assistance could be provided to local governments, and the menu of services offered could be made more extensive. Several states, including Iowa, have established revolving loan funds to finance energy efficiency upgrades in public buildings. Such a program could be expected to increase commercial sector energy efficiency in Kentucky by 1 percent by the year 2020 compared to the baseline, for a reduction of 94,227 tons CO_2 per year.

A much larger program would be appropriate in order to provide technical assistance and low-cost financing that would extend beyond the public sector and achieve efficiency retrofits in large numbers of private commercial buildings. Such a program would work in coordination with US EPA's *Energy Star Building* Program and the U. S. Department of Energy's *Rebuild America Program*, and would draw on the expertise and financial capabilities of private sector ESCOs as well. It is not unreasonable to project that a comprehensive program directed at energy efficiency retrofits in the entire commercial sector could reduce CO_2 emissions in the commercial sector by 5.0 percent, or 456,336 tons in 2020.

6.1.4 Industrial Sector-Expand the Scope of Energy Efficiency Services Provided by the Industrial Assessment Centers and the Kentucky Pollution Prevention Center

E. I. DuPont in Louisville, a Climate Wise partner and leader in reducing GHG emissions, already has plans to reduce its energy consumption per pound of product by 30 percent its Louisville facility. Similar experiences can be documented for other industries and agencies in Kentucky. Programs similar to those at MSD and DuPont have

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[111] The MSD program is administered by Ms. Sarah Lynn Cunningham, P.E.

been developed and encouraged by the University of Louisville Industrial Assessment Center, the Kentucky Pollution Prevention Center, the Energy Stars Building and Green Lights programs, the Louisville Resource Conservation Council, several utility sponsored commercial and demand-side management initiatives, and the Department for Natural Resources' Division of Energy. Collectively, these programs appear to reach out to virtually every segment of the Commonwealth's industrial sector and, in a few instances, even overlap.

A number of corporate executives have been interviewed to determine what types of incentives would be most effective. Responses have varied, but the one theme that has remained constant has been the call for an incentive system that identifies the capital cost of reduction and the amount of GHG removed. The Kentucky Industrial Development Act (KIDA), which is administered by the Kentucky Economic Development Finance Authority (KEFDA), provides tax credits for corporations, partnerships, sole proprietorships, or business trusts that establish plants or expand existing manufacturing operations in Kentucky.   As presently structured, the project must involve a minimum investment of $500,000 and create at least 15 new jobs for persons subject to Kentucky income tax to be eligible. A limit of $10,000 in tax credit is imposed for each job created.

The initiative proposed herein is to have the Legislative Research Commission (LRC) review the circumstance of corporations like DuPont that have already spent millions in reducing GHG emissions to determine how best to amend the KDIA to provide assistance or, if that is not deemed appropriate, to determine if new legislation is needed instead to achieve this goal. Substantial tax incentives are going to be needed in this area and it appears that legislation like the KDIA, or a set of KDIA amendments, will be necessary to accomplish any significant reductions.

The return from this investment is difficult to quantify with exact figures. However, it is reasonable to anticipate a truly significant reduction in GHG emissions if a suitable and fair systems of incentives can be found.

The three Industrial Assessment Centers (IACs) that serve Kentucky businesses and the Kentucky Pollution Prevention Center (KPPC) are currently providing valuable services to industrial firms, particularly small and medium-sized firms. Staff and budgets

at these institutions, however, are limited, which limits the number of firms that can be served.

The University of Louisville IAC team visited 30 plant sites during the 1996 fiscal year. Potential total energy savings projected on the basis of these visits were 13,410 million Btu in electricity generation and 20,124 million Btu in use of natural gas. A drop of 5,251 kW in electricity demand was also projected if the visit recommendations were put into action.[112] It is not known, however, how much of this potential was realized.

Application of the *EPA Workbook* methods utilized in Phase I of the study for conversion of coal and gas combustion figures to CO_2 emissions projects a reduction of 6,757 tons CO_2 per year or, for the 30 plants visited, an average of 225 tons CO_2 per year per site visited.[113] If it is assumed that approximately 50 percent of 1,007 plants in the University of Louisville IAC area are in Kentucky, extension of the savings projected for the 30 plants visited to half of the 1,007 possible gives a savings of 113,288 tons of CO_2 year potentially available in the light industrial sector. This analysis assumes, of course, that the electricity and natural gas saved will not otherwise be "spent" in generation of electricity to be sold to other end-users.

A policy option to expand the size of these programs, and to provide easily-used methods for firms to finance the energy efficiency measures that are recommended, could substantially increase the number of firms served and the rate at which they implement efficiency measures. The estimated reduction in CO_2 emissions in the year 2020 of 113,288 tons corresponds to an efficiency improvement of 0.3 percent in the industrial sector.

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[112] Hall, Rebecca Ann ; *Assessment of Metal Roof and Wall Insulation for Industrial Energy Conservation,* Master of Engineering Thesis, Department of Mechanical Engineering, December 1997, p.4. Savings in Btu electric (13,410 million Btu) and drop in demand (5,251 kW) document two different aspects of the IAC effort. The first records how much electricity would actually be saved (in Btu units) if all of the recommendations were put into affect. The second records what the drop in demand for electricity would be as a result. Industries are billed on the basis of demand as well as energy consumption, and a drop in this figure results in a lower bill. Thus, two means of cost reduction come about for industry as a result of reducing the amount of electricity used.

[113] The EPA workbook methods project emissions of 1,171 tons CO_2 for 20,124 million BTU for heating using natural gas. The 13,410 million BTU savings in electricity production was projected to reduce emissions by 5,586 tons CO_2 given a 28 percent efficiency of conversion of heat from coal combustion to electricity.

There is a limit to the GHG reduction potential that can reasonably be expected to result from the type of voluntary, outside technical assistance provided by the IACs and the KPPC. To achieve a larger impact in the industrial sector, other barriers besides the lack of technical information need to be overcome, *i.e.*, lack of capital for energy-related investments and insufficient return on investment (given Kentucky's low average energy prices). The institution of tax credits , a low-interest revolving loan fund, or other financial incentives to encourage industrial efficiency investments can address these barriers and magnify the measurable savings. Indeed, much greater reductions can be anticipated if sufficient funding and incentives are made available in support of actual plant process upgrades to more efficient systems as compared to just tightening up heating and cooling systems. An estimated reduction in CO_2 emissions in the year 2020 of 5,531,419 tons, corresponding to an efficiency improvement of 25 percent in the industrial sector, would not be an unreasonable expectation given such support.

6.1.5 Transportation Sector - "Feebates" (fees coupled with rebates) to Encourage Purchase of Fuel Efficient Vehicles

A recent study of scenarios for U. S. carbon emissions reductions developed by the nation's five national laboratories states categorically that "improved technological efficiency has been the most critical factor in energy trends." The automobile of course is a perfect example. For passenger cars fuel economy improved at a rate of 5 percent per year between 1972 and 1988, and this trend is expected to continue if not get higher.[114] Westbrook notes that 70 percent of the gain in fuel economy made between 1976 and 1989 was due to a shift to smaller cars that offer "the combination of weight reduction, improved transmissions, tires, and aerodynamics, widespread use of fuel injection, various engine improvements, and wider use of front wheel drive."[115] Recent shifts in the market to light trucks and larger cars may have halted this trend and partially reversed

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[114] Duleep, K. G.;*Scenarios for U. S. Carbon Reductions;* Oak Ridge, Lawrence Berkley, Argonne, National Renewable Energy and Pacific Northwest National Laboratories: Chapter 5, p. 5.1[http://www.ornl.gov/ORNL/Energy-Eff/CON444/].
[115] Westbrook, F. W. , *Allocation of New Car Economy Improvements, 1976-1989: Synopsis",* submission to Oak Ridge National Laboratory as quoted by Duleep, K. G.;*Scenarios for U. S. Carbon Reductions;* Oak

it. Little if any improvement is attributed to car pools, or to shifts to other forms of transportation.

It appears from this analysis that if policy makers intend to bring about significant reductions in GHG emissions in the transportation sector in Kentucky, they will do so only if a way is found to encourage the purchase of lighter, fuel-efficient cars. The nature and extent of the incentive, however, is open to some debate although it has been determined that no such incentives exist now.

The idea of a "feebate"- a combination of fees and rebates- is to encourage the manufacture and sale of energy-efficient light vehicles by applying fees to the sale of inefficient models and paying rebates for highly efficient models. At the state level, the feebate system could be designed to be revenue-neutral in that the fees could be set to balance the total costs of the rebates plus the costs of administering the program. The effect of vehicle buyers' decisions on overall transportation GHG emissions is a function of the size of the fees and rebates.

Although the concept is simple, a number of complicating factors need to be addressed in implementing a state-level feebate program. These include the treatment of light trucks, the issue of domestic and foreign manufacturers, and the legality of instituting a state policy that may be seen as duplicating the Federal fuel economy standards. Careful program design, however, can address such concerns.[116]

A feebate system instituted at a relatively low monetary level might yield a 5 percent improvement in efficiency for a reduction in 2020 of 1,244,404 tons of CO_2, while a more steeply inclined schedule of fees and rebates leading to a 10 percent improvement in efficiency could yield a reduction of 2,392,273 tons.

Energy conservation programs in this area are noticeably absent in Kentucky. Some reductions do occur as a spin-off of VET programs and, to a lesser extent, from the sale of RFG gasoline, but these are minor in comparison to what could be accomplished through the purchase of fuel efficient vehicles. All of the major car makers have

Ridge, Lawrence Berkley, Argonne, National Renewable Energy and Pacific Northwest National Laboratories: Chapter 5, p. 5.1[http://www.ornl.gov/ORNL/Energy-Eff/CON444/].
[116] *Feebates for Fuel Economy: Market Incentives for Encouraging Production and Sales of Efficient Vehicles,* John M. DeCicco, Howard S. Geller, and John H. Morrill, 1992, American Council for an Energy-Efficient Economy, Washington, D.C.)

announced plans to introduce vehicles on the market in the near future, most of which are gasoline powered and which will drastically reduce the amount of fuel consumed per mile driven. These cars will supplied mostly to California and the Northeast but can be expected to be found nation wide by 2001.

The initiatives outlined above would influence a number of issues in the Commonwealth in addition to fuel economy. Air quality in the nine problem counties would certainly benefit, as would some aspects of the economy if it is assumed that savings were used to purchase other goods. Indeed, the suggestion of offering tax incentives for the purchase of fuel-efficient cars seems to fit in the category of a "common sense initiative" and might best be served by an Environmental Quality Commission (EQC) resolution calling first for establishment of a work group of experts, government officials, industry representatives and public representatives assigned the charge of coming up with an equitable plan for such incentives. The proposal of tax incentives and feebates for fuel efficient cars, while appearing simple, is actually quite complex. A detailed proposal as to how this might be done is beyond the scope of this report, but the suggestion of a serious study of the possibility made by a well-balanced group under EQC guidance is entirely reasonable.

6.2 Renewable Energy Sources

6.2.1 Solar Heating for Low-Temperature Applications

Although Kentucky is not located in the part of the United States with the largest amount of solar insolation, there are many low-temperature applications which could use solar energy if the economics were slightly more favorable. These include heating water for swimming pools, preheating water in the commercial and residential sectors, drying crops, and preheating air for industrial and commercial space heating of buildings. Two possible mechanisms to improve the economics to the point where solar heating is cost-effective are: (1) A fund established to support renewable energy projects; and (2) State income tax credits for individuals or corporations that install solar heating equipment.

The first option is being implemented in certain states such as California that have restructured their utility industries. The California restructuring plan allocates $540 million over the period 1998-2001 to provide payments to producers and consumers of

electricity from renewable sources, including solar, wind, biomass, geothermal, small hydro, methane from landfills, and animal manure. The system is partly market-based in that producers bid to supply renewable power, and those requesting the lowest subsidy per kilowatt-hour are funded first.

State income tax credits were allowed on certain types of solar heating equipment in Kentucky during the early 1980s. Although many solar water heating systems were installed as a result of the tax credits, ongoing servicing and parts for the systems became less available over time. When the tax credits ended, some of the companies went out of business, leaving customers unable to obtain service for their solar heating systems. It should be possible, however, to design a tax credit program that corrects for the problems experienced during the 1980s.

It is estimated that a small renewable energy fund or a modest income tax credit could displace 0.2 percent of the energy used in the residential, commercial, and industrial sectors, reducing CO_2 emissions by 128,192 tons per year, while a larger-scale program could displace 1.0 percent of the energy used in these sectors in the year 2020, reducing CO_2 emissions by 596,560 tons per year.

6.2.2 Solar Electric Systems

The cost of technologies that convert sunlight directly to electricity, known as photovoltaic or "PV" systems, has fallen steadily since their introduction in the 1960s as a means of providing energy in satellites and spacecraft. Though the capital cost per installed kilowatt is still too high for PV systems to displace baseload electric power, it is cost-effective today in certain specialized applications. PV is used today on Kentucky highways to supply power to flashing warning signs, and it can be the lowest-cost option in other remote areas, where the cost of extending a power line or using a diesel generator would be prohibitive.

During the next several years, it is likely that the Federal government will institute incentives such as tax credits to encourage the installation of PV systems on commercial buildings and homes. Kentucky could magnify the impact of such national policies by instituting state-level policies such as those discussed above (Section 6.2.1).

It is estimated that a small program to subsidize PV electricity or a modest income tax credit could displace 0.1 percent of the energy used in the residential and commercial sectors reducing CO_2 emissions by 20,174 tons per year, while a larger-scale program could displace 0.7 percent of the energy used in these sectors in the year 2020, reducing emissions by 140,545 tons per year.

6.3 Reduce Emissions of Chloroflurocarbons (CFCs)

In the course of estimating GHG emissions for the year 1990, it was estimated that the single Kentucky manufacturing plant operated by the E. I. DuPont Company emitted 937 tons of HCFC-22 and 1,499 tons of HFC-23. (HFC-23 is a byproduct of HCFC-22 production.) These projections were based on design criteria available at the time and upon statistical data published on a national basis. DuPont has since reported the exact figures for both compounds, and others.[117] The reported data suggest that the emissions estimated for 1990 Phase I inventory were lower than actual, although in some years since 1994 the true emissions and inventory estimate are comparable.

Table 7. HCFC-22 and HCFC-22 By-Product Emissions (HFC-23): 1990-1996

Year	HCFC-22 Emissions in tons per year	HFC-23 Emissions in tons per year
1990	3,425	2,379
1991	1,275	2,766
1992	1,840	3,336
1993	2,690	2,494
1994	1,033	1,835
1995	2,888	1,851
1996	1,953	1,935

[117] DuPont fluoroproducts are reported as SARA 313 emissions. Reports for HCFC-22 were not required before 1994 but duPont has listed the figures nonetheless. The copy of this data received by Hugh T. Spencer from Mr. Carl Hilton, Environmental Affairs Officer for the Louisville duPont plant, also contained emissions for HFC-23.

DuPont has already spent $750,000 in an effort to reduce HFC-23 emissions to 50 percent of the 1990 level by 1998. Another $1,000,000 to $5,000,000 expenditure is projected as the costs of installing a complete recycle system for HFC-23. This plan, if it becomes operational, will remove essentially all fugitive HFC-23 emissions. Thus, it appears entirely feasible to consider a 100 percent reduction for HFC-23 emissions by 2020.

The results achieved between 1990 and 1998 by the ongoing pollution prevention program that has been put in place at the DuPont plant give rise to the baseline assumption that CFC emissions will decrease by 50 percent by the year 2020. Additional policies such as tax incentives may enable DuPont to make the capital investments necessary to reduce its emissions further. A modest incentive might be expected to reduce remaining HFC-23 emissions by another 25 percent, providing a reduction in CO_2 equivalent emissions to 3,131,004 tons per year by 2020. A more aggressive incentive leading to the complete removal of fugitive HFC-23 emissions would result in a reduction of 6,258,309 tons CO_2 equivalent per year.

6.4 Methane Capture and Recovery

Eleven sources of methane were quantified in Phase I of this study as components of the 1990 emissions inventory. These are listed in the table below in the order of impact.[118]

Table 8. 1990 Inventory Methane Emissions for Kentucky

Activity and Gas Type	Tons CH_4 Emitted per Year for 1990	Equivalent Tons per Year as CO_2	Percent of State Total as CO_2
Coal extraction	900,083	19,801,826	9.63
Domestic animals	155,463	3,420,189	1.66
Landfills	126,066	2,773,457	1.35
Manure management	37,629	827,839	0.40

Nat. gas distribution	19,553	430,175	0.21
Wastewater	8,022	176,493	0.09
Crude oil transport	384.7	8,463	0.004
Gas-oil well vent	293.3	6,453	0.003
Oil production	91.6	2,015	0.001
Gas production	5.71	126	0.00006
Crude oil storage	0.66	15	0.00001
Total	1,247,592	27,447,051	13.35

Methane emissions do make up a significant part of Kentucky's contribution, with coal-bed methane as the leading source. Other sources releasing significant amounts are domestic animals, manure and landfills. Of these, coal-bed methane and landfills offer the best opportunities for reduction. Methane emissions from domestic animals come via metabolic activity. Some of the programs in operation today designed to reduce methane emissions from domestic animals are discussed in Chapter 4. Emissions from other sources, with the possible exception of manure management, are too small to make a significant impact.

6.4.1 Coal-bed Methane

Coal-bed methane, except as captured as part of an existing producing natural gas field, is not a well developed resource in Kentucky. Ownership issues and high capital costs associated with limited promise of return are complicating factors that together conspire to keep development and interest in this area at a low level. Some possibility for capture and utilization, however, does exist.

A modest tax incentive leading to the reduction of coal-bed emissions through methane capture could reasonably be expected to reduce direct losses by 0.1 percent by the year 2020. This would provide for a reduction equivalent to 23,349 tons of CO_2 per year. A more aggressive program leading to a 1 percent reduction in methane emissions would reduce the CO_2 equivalent emissions by 200,194 tons per year.

6.4.2 Landfill Gas (LFG)

As noted in Section 5.5, at least twenty landfills in Kentucky are estimated by EPA to have the potential to support economically viable gas-to-energy projects, although no landfills in Kentucky currently have existing energy recovery projects. However, one is planned for the near future. The CO_2 emission reductions achievable by LFG to energy projects in Kentucky could approach 3,600,000.

Modest tax incentives leading to development of a capture system for at least 20 percent of the 3,600,000 figure are possible, or for a reduction of 720,000 tons CO_2 per year. A more aggressive incentive might result in the capture of up to 40 percent of the methane from this source for a reduction of 1,440,000 tons of CO_2 equivalent per year.

6.4.3 Manure Management Programs

Manure management programs designed to capture methane from anaerobic digestion of animal waste have been successfully developed in other states, but only after the application of considerable capital. The return on such investments, while limited, is usually sufficient to defer costs of operation. Secondary benefits from such programs such as odor control and reductions in stream pollution may in fact be the more important reasons for their application.

A modest effort in the form of low-interest loans, or of tax credits, designed to off-set the capital costs of developing manure management programs can reasonably be expected to reduce emissions in this sector by 5 percent in the year 2020, to give an equivalent reduction in CO_2 of 38,232 tons per year. A more intense program providing a 20 percent reduction would reduce emissions by 141,827 tons per year. The Commonwealth already offers funds and support for manure management programs through cost-share arrangements and revolving loan systems.

6.5 Re-Powering (Fuel Switching) Initiatives for the Utility Industry

The traditional post World War II coal-fired utility generating station built between the years 1945 to 1990 utilized coal combustion to generate steam which in turn passed through a steam turbine to generate electricity. Many of these plants are now due for replacement by virtue of their age, a circumstance which comes at the same time as

electric industry restructuring, new and demanding air pollution requirements (NO_x and $PM_{2.5}$), and reductions in demand as a result of energy efficiency gains. These realities immediately raise several questions. Specifically, (1) how will plants of the future be powered; (2) what size will they be; (3) what will their service areas be; (4) where will they be located; and (5) what will their future contributions be to the Commonwealth's greenhouse gas emissions. Clearly, a great deal is going to happen in the utility industry in the near future. This begs the question: "Can the changes be orchestrated in a way which will result in the reduction of GHG emissions while preserving the economy of the coal mining industry?" The answer is "yes" if re-powering or fuel switching is taken into account in which the primary fuel is switched from coal to natural gas, or from coal to a coal ⊃ gas conversion system.

In the following discussion, power plants fueled by natural gas are referred to by the acronym NGCC, which stands for Natural Gas Combined-Cycle. Coal ⊃ gas conversion systems are referred to as IGCC systems, which stands for Integrated Gasification Combined-Cycle. Both have a role to play in the future of the Commonwealth's utility and coal industry, and in initiatives undertaken to reduce GHG emissions. The utility industry was identified in Phase I of this study as being responsible for 37 percent of the State's emissions. Thus, policy initiatives dealing with this sector of the economy will have a significant impact.

The basic nature of an NGCC system is shown in the diagram below:
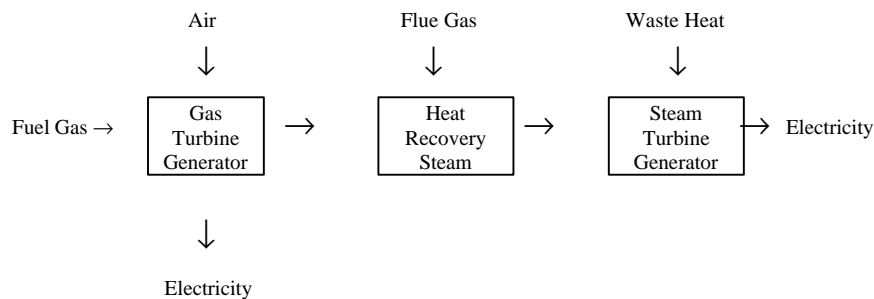
Estimates taken from recent national studies indicate that annual carbon emissions can be reduced nationally by up to 238 million metric tons of carbon (MtC) through re-powering with NGCC systems.[119]

IGCC systems are identical to NGCC systems except for the source of the fuel. The fuel gas in NGCC systems is natural gas. In IGCC power islands, the fuel gas is derived from coal, or as in the case of advanced fuel technologies (AFT), from a combination solid waste and coal. Working IGCC and AFT/IGCC systems, and some NGCC systems, are now operational in the U. S. and in Fife, Scotland.[120]

For IGCC systems the coal is crushed prior to gasification and then partly burned through the addition of steam and air. The fuel gas passes through a heat recovery system and cleanup section where particulates and sulfur are removed. From this point the fuel gas goes to a gas turbine generator as shown in the figure above. In the AFT/IGCC system the design is the same with the exception of the solid fuel feed stream. The AFT system combines coal and domestic solid waste to form fuel briquettes which in turn go on to the gasifier. Tipping fees paid to the operator for solid waste disposal offset the cost of the coal making the AFT/IGCC system competitive with NGCC systems. The typical generating capacity of AFT/IGCC systems on the market today is 400 MW.

The tax incentives needed to fund even a modest re-powering schedule calling for construction of two to three 400 MW units (NGCC, IGCC or AFT/IGCC) would involve a significant amount of money. The savings gained, however, in terms of CO_2 emission reductions would also be considerable. Policies leading to replacing approximately 10 percent of Kentucky's 1990 coal-fired generating capacity of 12,000 MW beyond the 10 percent basecase figure would in turn reduce CO_2 emissions by 3,652,701 tons per year in 2020. These policies would be in support of construction of three 400 MW units for the basecase replacement and another three units to give a total of 20 percent replacement by

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[119] *Scenarios for U. S. Carbon Reductions;* Oak Ridge, Lawrence Berkley, Argonne, National Renewable Energy and Pacific Northwest National Laboratories: Chapter 7, p. 1[http://www.ornl.gov/ORNL/Energy-Eff/CON444/].

[120] The number of IGCC plants operating in the U. S. is growing. DOE has recently made Tampa Electric's Polk Power plant the fifth plant since 1991 to receive a clean coal facility prestiguous award. Others are sure to follow. An AFT/IGCC plant is also now operational in Fife, Scotland. The *Environmental Statement* prepared by Hannah, Reed and Associates for the 400 MW AFT/IGCC plant at Fife was made available to the author on a loan basis. This document is not generally available but persons interested in

2020. More aggressive policies leading to the construction of six 400 MW units in addition to the three for the basecase for a total of nine would replace up to 30 percent of the coal-fired baseload and provide a reduction of 10,950,702 tons CO_2.

this technology may learn more about it by contacting Global Energy Corporation, 312 Walnut Street, Cincinnati, OH.

7. POTENTIAL FOR GHG INCREASING CARBON SEQUESTRATION THROUGH EXISTING REFORESTATION PROGRAMS

The most recent survey available for Kentucky's timber resources (1988) lists 12,532,800 acres classified as timberland distributed as shown in the Table 7.[121] The distribution of timberlands by county is shown in Figure 9. With the exception of Owen County, it is evident that forest cover in the Bluegrass is limited. Timberland cover is more extensive in Eastern Coal Field, particularly in Pike, Breathitt, and Harlan Counties, and in the counties close to, or forming the eastern boundary of the Western Coal Field. Timberland cover through the Mississippian Plateaus is not as extensive as in the coal fields, but coverage in this area is not insignificant.

Table 9. Distribution of Kentucky Timberlands as of the Most Recent Survey (1988)

Classification	Acreage Covered
Timberlands	12,347,300
Other forest	37,600
Reserve forest	147,700
Total timberlands	12,532,600
Non-forestlands	12,694,200
Total	25,226,800

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[121] The United States Forest Service provides listings of timberland cover under the heading of "State Forest Inventory and Analysis (FIA)" at http://srsfia.usfs.msstate.edu/scripts/twig/kytab.com. The principal source for the data given for Kentucky is: Alerich, Carol L., *Forest Statistics for Kentucky*: *1975 and 1988*, US Department of Agriculture, Forest Service, Northeast Forest Station, Resources Bulletin NE-117.

Figure 9. Distribution of Kentucky Timberlands as of the most Recent Survey (1988)

With the exception of Owen County, it is evident that forest cover in the Bluegrass is limited. Timberland cover is more extensive in Eastern Coal Field, particularly in Pike, Breathitt and Harlan Counties, and in the counties close to, or forming eastern boundary of the Western Coal Field. Timberland cover through the Mississippian Plateaus is not as extensive as in the coal fields, but coverage in this area is not insignificant.
The counties with the largest tracts of timberlands are:

Pike	*423,000 acres*
Breathitt	*283,000*
Harlan	*272,000*

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Distribution of Kentucky Timberlands as of the most Recect Survey (1988)

Tousands of Acres as Timberland
0 - 20
21 - 102
103 - 162
163 - 254
256 - 423

KIESD - CEE
University of Louisville
Speed Scientific School

KY NREPC
Division of Energy

U. S. EPA
Planning, Policy and Evaluation
Federal Assistance No. CX822849-01-0

The University of Louisville
Speed Scientific School
Air Quality and Emission Laboratory

The University of Louisville
ULCGIS
Center for Geographic Information System

The distribution of Kentucky timberlands by ownership category is given in Table 10.[122] It is evident from these data that private individual ownership far outweighs any other category, especially if combined with ownership classified as "farm-ranch." Together these two groups control 82 percent of Kentucky's timberlands.

Table 10 . Distribution of Ownership for Kentucky's Timberlands

Category	Acres of Timberlands	Percent
National Forest	698,900	5.66
Bureau of Land Mngt.	0	0.00
Tribal Trust	0	0.00
Misc. Federal	235,200	1.90
State	140,000	1.14
County or Municipal	0	0.00
Forest Industry	204,500	1.66
Farm-Ranch	1,451,300	11.75
Private Corporation	981,700	7.95
Private Individual	8,635,200	69.94
Total	12,347,300	100.00

Non-government ownership summed over all private and corporate categories controls a total of 91 percent of the Commonwealth's timberlands.

The listing of municipal and county forest listed as "zero" for Kentucky in the National Forest Service FIA tables is not technically correct. Acreage in this category for the Commonwealth, while locally significant, appears to have been too low to be considered in the FIA database. An inventory of parks, unique areas and habitats was developed for Kentucky in 1977 by Stine.[123] This author identified 158 parks in the Jefferson County-Louisville Metropolitan area alone. Twelve of these were listed as being over 100 acres and one, the Jefferson County Forest, was listed as having an area of

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[122] *Ibid., "State Forest Inventory and Analysis (FIA)"* http://srsfia.usfs.msstate.edu/scripts/twig/kytab.com.
[123] Stine, Denise Marie, *An Inventory of Parks, Unique Areas, and Habitats in Kentucky,* Master of Engineering Dissertation, Environmental Engineering, Speed Scientific School, University of Louisville, 1977.

over 1,000 acres. Stine's work is also interesting in that it provides one of the earliest technical references to an extensive acreage (1,500 acres) of "untouched" forest on the south face of Pine Mountain. This forest tract has since been declared true old-growth and has been purchased in part by the State. It is now known as Blanton Forest and actually comprises some 2,000 acres.

Kentucky's old growth forests comprise some of the most beautiful wildlife habitat to be found in the United States, or anywhere in the world for that matter, but forests in this category do not offer a benefit in carbon sequestration. Their acreage is small, now no more than 2,500 acres state-wide, and they are mature. Managed timberlands that are actively being harvested and then replanted do, on the other hand, offer a benefit, as do lands (crop, pasture, mined terrain or urban "built" properties) that return to forest cover. Collectively, crop and pasture lands were returning to forest in Kentucky at a rate of 20,000 acres per year as of 1990. Mined lands were also then returning to forest in Kentucky at a rate of approximately 30,000 acres per year, primarily in the eastern hardwood forest of Appalachia. Managed timberlands, however, are present in Kentucky in excess of 12,000,000 acres and thus offer a far more extensive opportunity for carbon sequestration. All concerned with the Commonwealth's timber resources agree that we are in a period of "boom" growth for the industry which currently is putting up to $3 billion dollars per year into the State's economy.[124]

Figures for the 1990 sawn lumber harvest by board feet per county are available for Kentucky and were cited in the 1990 Phase I Inventory Study. The total for the state from this source was 752,098,273 board feet.[125] This harvest was converted to cubic meters by use of the standard conversion factor: 1,000 board feet = 3.48 m^3.[126] Thus,

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[124] Melnykovich, Andrew; *Forest at a Crossroads, January 25, 1998; Kentucky Looking to Virginia and West Virginia on Logging Laws, January 26, 1998; Can Kentucky Learn from Missouri Forest?;* The Courier-Journal, Louisville, Kentucky. The Melnykovich articles provide an in-depth three-part series detailing the nature of Kentucky's timber sales boom. The same points are made as above; namely, that the annual rate of timberland harvest and the actual amount available are poorly known statistics at this time.
[125] *1990 Sawn Lumber Production for Kentucky;* Natural Resources and Environmental Protection Cabinet, Department for Natural Resources, Division of Forestry, 627 Comanche Trail, Frankfort, Kentucky 40601.
[126] The figure of 3.48 m^3 per 1,000 board feet was provided by Dr. Robert Muller, Chairman of the Department of Forestry at the University of Kentucky. The number comes from the work of Carol L. Alerich. This conversion factor is remarkably variable. The CRC Handbook of Chemistry and Physics for example gives 1 board feet = 2,359.7372 cm^3 which in turn gives 1,000 board feet = 2.36 m^3. The two conversion factors differ by a factor of 1.47. Alerich, however, does provide a thorough analysis and documentation for his figure 3.48 m^3 per board foot explaining the reasons for the difference.

cubic meters harvested in 1990 = 752,098.723 x 3.48 = 2,617,302 m^3. Conversion of this figure to cubic feet gives: 2,617,302 m^3 x 35.314667 ft^3/m^3 = 9.24E+07 ft^3 for sawn lumber. Birdsey projects 2,034 cubic feet per acre for a mature hardwood forest in the central U. S.[127] Division of the gross harvest figure by this number gives: 9.24E+07 ft^3 ÷ 2,034 ft^3 per acre = 45,428 acres. The industry has grown 1.5 fold since 1990. Thus, an estimate of 68,000 acres per year for the current rate of forest land-cover removal in Kentucky is realistic. This estimate, however, comes with a large error margin and should be referred to as "an annual acreage equivalent to 68,000 acres of harvest quality timber."

The Division of Forestry reported 897 million board feet of lumber produced in Kentucky in 1995 with an average harvest rate of 3,000 board feet per acre.[128] These figures suggest harvest acreage of 897,000,000 ÷ 3,000 = 299,000 acres for 1995, a figure three times the 1998 estimate developed using Birdsey's number of 2,034 cubic feet per acre. This estimate must also be taken as having a large error margin, although it may well be closer to the truth for Kentucky. The truth is that exact figures for forest harvest in Kentucky are not known by any source in the Commonwealth, but it does appear that the range is currently on the order 70,000 to 300,000 acres per year. A figure of 100,000 has been adopted for this study.

7.1   Potential for increasing the urban forest

Sampson *et al.* after developing a careful analysis of the potential for urban forest cover concluded that the "role of U. S. urban and community trees in affecting the global carbon dioxide balance is admittedly modest".[129] These authors estimate that work to improve urban forest could potentially provide a 2 to 3 percent reduction in national emissions which, while small, would still be of some importance.

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[127] Birdsey's projections [as cited by Neil Sampson and Dwight Hair, *Forest and Global Change Volume 2: Forest Management Opportunities for Mitigating Carbon Emissions,* An American Forest Publication, Washington, DC, Appendix 2 through Appendix 4, 1966] suggest 2,034 cubic feet of timber volume per acre for a mature oak-hickory forest in the central states.

[128] Personal communication from Larry Lowe, Division of Forestry to Geoff Young, Division of Energy, February 12,1998.

[129] Sampson, Neil R., Moll, Gary A. and James Kielbaso, *Opportunities to Increase Urban Forest and the Potential Impacts on Carbon Storage and Conservation,* Forest and Global Change, Volume 1, edited by

Sampson and Kielbaso developed a spreadsheet model for urban sequestration using national figures. This model is readily adaptable to the state level and has been so structured for the Kentucky Phase II project.[130,131] The model is of particular value in that it takes improvement due to cooling and heating effects into account as well as carbon sequestration. The revised model estimates a removal rate in tons CO_2 per year over the period of 2000 to 2020 for the Commonwealth of Kentucky.

Sampson and Kielbaso considered 50.3 million acres total in the United States to be in the category of "built-urban." This comprises approximately 2 percent of the U.S. land cover. The extent of built land is not known exactly for Kentucky, but it is believed to be greater than 2 percent.[132] A figure of 4 percent for the Commonwealth gives approximately 1,000,000 acres of "urban-built" land which is a reasonable figure. The Sampson and Kielbaso model projects a potential reduction in CO_2 emissions of 2,728,879 tons per year by 2020 for this land coverage. Such a reduction would, of course, only be realized if policies were adopted to further encourage urban tree planting programs.

7.2   Potential for increasing rural and managed forest

The degree to which farm, mined properties, and managed forest tracts returning to forest can be counted on to sequester carbon may be estimated from the data provided in Figures 15 through 17.[133] Several means are available for utilization of these curves. The polynomial functions [$f(x)$] can be reorganized to give CO_2 equivalents sequestered for a given interval (x) as follows:

Tons CO_2 sequestered per interval = [$f(x)$]*acres returned*(1000/2000)*3.67,

where;

Neil Sampson and Dwight Hair, An American Forest Publication prepared with the support of The USDA, USEPA, DOE and the American Forest Council, (1992), p. 51.

[130] See Report Appendix

[131] Sampson, Neil and J. James Kielbaso, *Construction of a National Urban Forest Impact Model, Ibid.,* Forest and Global Change, Volume I, p. 281.

[132] Personal communication with Dr. Bill Dakan, Department of Geography and Geosciences, University of Louisville, Louisville, Kentucky, December 1997.

[133] Birdsey, Richard A., as cited by Neil Sampson and Dwight Hair, *Forest and Global Change Volume 2: Forest Management Opportunities for Mitigating Carbon Emissions,* An American Forest Publication, Washington, DC, Appendix 2 through Appendix 4, 1966.

[$f(x)$] = the polynomial function,
acres returned = acres returned to forest,
1000 = 1000 multiple needed to convert result (y) from 1000 pounds per acre to pounds per acre,
2000 = 2000 pounds per ton, and
3.67 = 3.67 equivalents of CO_2 per unit mass of carbon sequestered.

An example tabulation for pasture to forest is given in Table 12 along with the differential for sequestration. The figures shown are for the return of 10,000 acres of pasture land every year beginning in the year 2000 and continuing through 2020. This figure presumes that the historical rate of return to forest will decrease over time from its current level of 20,000 acres per year to an average of 10,000 acres per year from 2000 through 2020. A significant portion of farmlands converted to alternate use during this time frame, if still being lost at the higher rate 20,000 acres per year in 2020, are expected to go to urban-built property in contrast to forest. The first 10,000 acres returned (in 2000) will, of course, have accumulated more CO_2 over the twenty-year period than the second 10,000 acres returned (in 2001) given that these lands will have had one more year to grow.   Obviously, as the year of return approaches 2020 the carbon sequestered approaches zero.

Table 11. Cumulative Carbon Sequestration for Pasture Lands Returned to Forest at a Rate of 10,000 Acres per Year

Year of Reversion	Interval (x) in years of accumulation out to 2020	Sequestration as Tons CO_2 per Interval (x)

2000	20	750,955
2002	18	676,857
2004	16	602,444
2006	14	527,750
2008	12	452,810
2010	10	377,661
2012	8	302,338
2014	6	226,874
2016	4	151,307
2018	2	75,670
2020	0	0
	Total CO_2 sequestration ➲	7,914,074

Figure 10. Regional Estimates of Forest Carbon for Fully Stocked Timberland with Average Management after Pasture Reversion to Forest

The polynomial functions [f(x)] can be reorganized to give CO_2 equivalents sequestered for a given interval (x) as follows:
Tons CO_2 sequestered per interval = [f(x)]*acres returned*(1000/2000)*3.67,
where;

> *[f(x)] = the polynomial function,*
> *acres returned = acres returned to forest,*
> *1000 = 1000 multiple needed to convert result (y) from 1000 pounds per acre to pounds per acre,*
> *2000 = 2000 pounds per ton, and*
> *3.67 = 3.67 equivalents of CO_2 per unit mass of carbon sequestered.*

Regional Estimates of Forest Carbon for Fully Stocked Timberland with Average Management after Final Clearcut Harvest

$$y = -6E\text{-}05x^3 + 0.0105x^2 + 0.915x + 125.73$$
$$R^2 = 0.9996$$

1,000 pounds carbon/acre

Years from Harvest

115
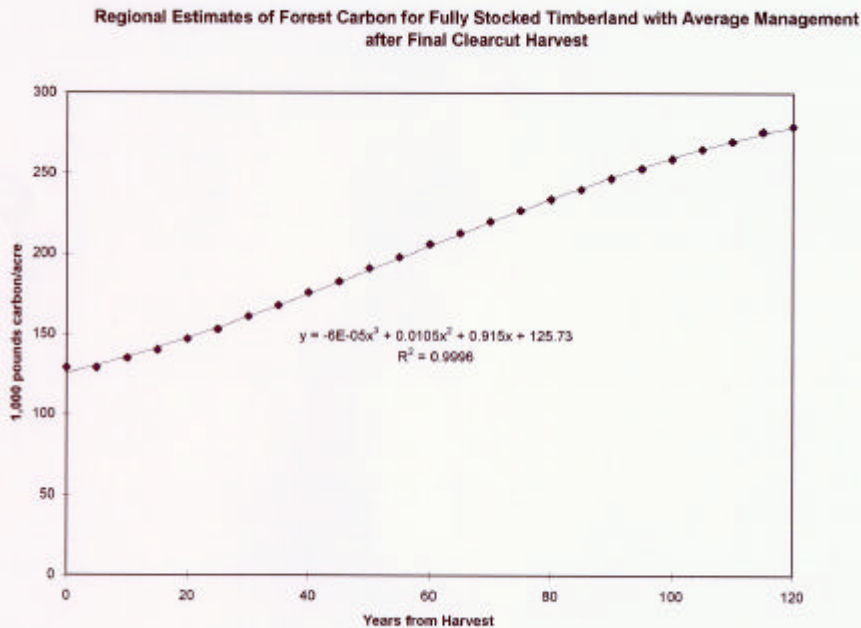
Figure 11. Regional Estimates for Forest Carbon for Fully Stocked Timberland with Average Management after Cropland Reversion to Forest

The polynomial functions [f(x)] can be reorganized to give CO_2 equivalents sequestered for a given interval (x) as follows:

Tons CO_2 *sequestered per interval = [f(x)]*acres returned*(1000/2000)*3.67,* where;

[f(x)] = the polynomial function,
acres returned = acres returned to forest,
1000 = 1000 multiple needed to convert result (y) from 1000 pounds per acre to pounds per acre,
2000 = 2000 pounds per ton, and
3.67 = 3.67 equivalents of CO_2 per unit mass of carbon sequestered.

Regional Estimates of Forest Carbon for Fully Stocked Timberland with Average Management after Cropland Reversion to Forest

$y = -5E-05x^3 + 0.0012x^2 + 2.1608x + 35.79$
$R^2 = 0.9998$
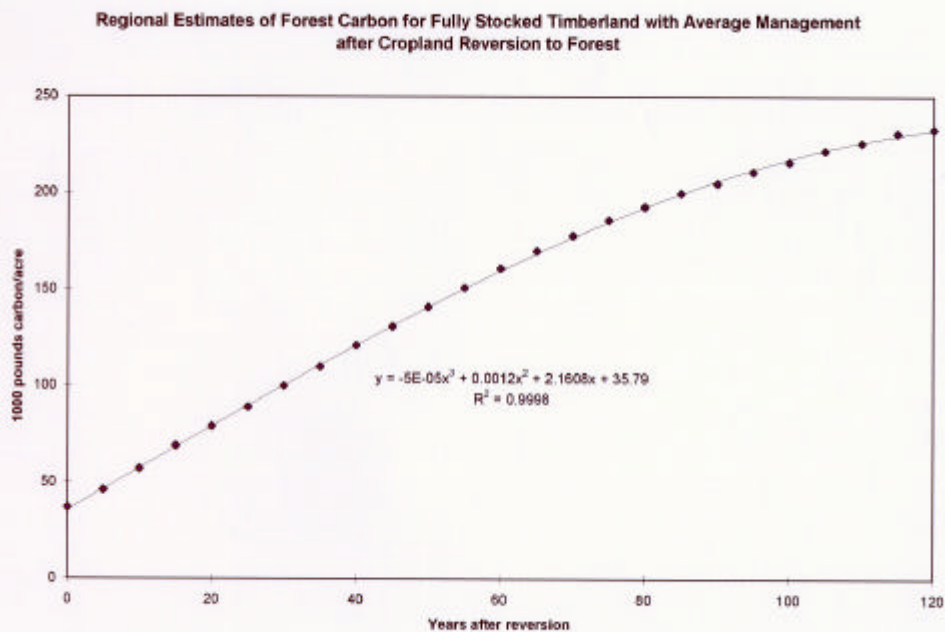
Figure 12. Regional Estimates of Forest Carbon for Fully Stocked Timberland with Average Management after Clear-cut Harvest

The polynomial functions [f(x)] can be reorganized to give CO_2 equivalents sequestered for a given interval (x) as follows:

Tons CO_2 sequestered per interval = [f(x)]*acres returned*(1000/2000)*3.67,
where;

[f(x)] = the polynomial function,
acres returned = acres returned to forest,
1000 = 1000 multiple needed to convert result (y) from 1000 pounds per acre to pounds per acre,
2000 = 2000 pounds per ton, and
3.67 = 3.67 equivalents of CO_2 per unit mass of carbon sequestered.

Regional Estimates of Forest Carbon for Fully Stocked Timberland with Average Management after Pasture Reversion to Forest

$y = -4E\text{-}05x^3 + 1E\text{-}05x^2 + 2.0624x + 48.186$
$R^2 = 0.9997$
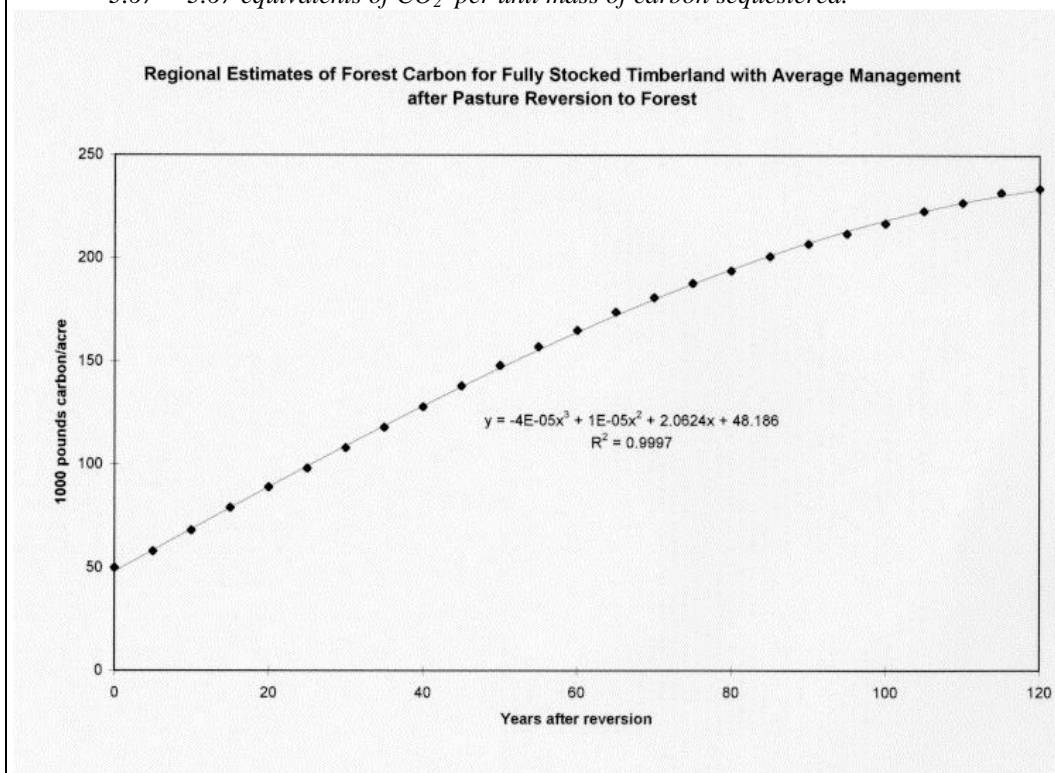
The figures in Table 12 were obtained by first determining from the equation above the sequestered CO_2 present at the start of the interval. For the case chosen as an example this figure turns out to be 884,213 tons CO_2 sequestered for the pasture acreage returning to forest. For this first calculation (x) is set equal to zero. Next, the CO_2 sequestered twenty years later is determined by applying the function with (x) set equal to 10. This figure is 1,653,169 tons CO_2. The difference between these figures (1,501,911 − 884,213 = 617,698) is the tonnage of CO_2 sequestered over the 20 year interval. For determination of sequestration over the interval 2001 to 2020 (x) is set equal to nineteen (19) years. The rest of the calculations follow this pattern with the sum of the twenty year experience being taken as the sequestration benefit for the period.

A tabulation of 2000 to 2020 projections for carbon sequestration for pasture, crop lands, timber harvest properties and for return of newly-mined lands to forest is given in Table 12. As noted above, this tabulation assumes that historical (1975 to 1990) trends in land use and conversion will continue through 2020.

Table 12. Potential for Carbon Sequestration from 2000 through 2020 for Return of Pasture, Crop lands, Harvested Timberlands and Newly-Mined Land to Managed Forest Cover

Source of land returned	Acres returned per year	Carbon sequestered as tons CO_2 by 2020
Pasture lands	10,000	7,914,074
Crop lands	10,000	8,349,378
Harvested timberlands	100,000	27,003,517
Newly-mined lands	30,000	12,091,127
Total	150,000	55,358,097

The 55,358,097 tons CO_2 cited in Table 13 fails to take into account the CO_2 released due to land conversion concomittant to surface mining. The rate determined for

land conversion emissions due to mining in the 1990 Phase I inventory was 4,025,273 tons per year. Assuming this rate holds constant over time, the net rate for carbon sequestration potential becomes $55,358,097 - 4,025,273 = 51,332,824$ tons per year in 2020, which is higher than the figure of 34,186,726 tons per year estimated for net sequestration in 1990. Timber harvest has increased since 1990, and the difference cited here can be accounted for by that factor.

7.3 Existing Programs for Reforestation and Forest Management

Interest in forest preservation and development in Kentucky, and in greenhouse gas emissions reduction, have brought a number of programs into being. These include legislative initiatives, mining reclamation initiatives, action taken by utilities and corporate landowners, extension service assistance in forest maintenance provided through the University of Kentucky, initiatives supported by the Environmental Quality Commission, local efforts in reforestation of city and county park lands, and the efforts of the Kentucky Division of Forestry. A brief review of these programs is provided below.

7.3.1 Reclamation Advisory Memorandum (RAM) Number 124

Current reclamation practice creates three circumstances inhibitory to the development of post-mined land to a forest resource. These are: excessive compaction of the rooting medium, selection of inappropriate rooting medium, and excessive competition from herbaceous ground cover species established to control erosion. RAM 124 addresses these issues. It was formulated through the NREPC after a recommendation made by the Environmental Quality Commission in the spring of 1996 in the form of a resolution given as a "Common Sense Initiative." The initiative directed the Department of Surface Mining Reclamation and Enforcement to initiate a high-priority and aggressive approach to promote reforestation as a viable post-mining land use. RAM 124 has been accepted by the Department for Natural Resources and its Division of Forestry as appropriate reclamation practice for those mined areas reclaimed

to a post-mining land use which requires the establishment of deep-rooted woody species.[134]

7.3.2 Tree Planting Programs Designed to Off-Set Greenhouse Gas Emissions

One utility with generating plants in Kentucky has begun to plant trees to offset GHG emissions. American Electric Power (AEP) recently planted 245,000 seedlings on 250 acres in the vicinity of its Carr site near Vanceburg, Kentucky, and in the area of its Big Sandy plant near Louisa, Kentucky.[135]

7.3.3 The Kentucky Forest Stewardship Program

The University of Kentucky, Department of Forestry Extension Service offers forest stewardship assistance to any land owner with 10 or more acres of timberland. The program is voluntary and comes without charge or obligation. Upon request the property will be visited by a professional forester and, if necessary, by representatives of the Kentucky Department of Fish and Wildlife Resources. A detailed management plan is submitted to the land owner, who then may apply the recommendations a desired.[136]

7.3.4 Division of Forestry Reforestation Programs

The Department for Natural Resources, Division of Forestry maintains extensive programs in urban and rural reforestation, and also provides advice and guidance to landowners and loggers. More than ninety percent of the Commonwealth's timberlands are owned by 400,000 private holders of relatively small parcels of land. The Division is assigned the difficult task of assisting these landowners in development of marketable timber and in the management of timber harvest. It is estimated that less than 12 percent of Kentucky's annual harvest of some 800 million board feet is managed by a professional plan.[137]

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[134] More detailed information on the EQC initiative and RAM 124 may be obtained from: [http://www.state.ky.us/agencies/eqc/mineresolution.html] and [http://www.coaleducation.org/reg-agcm/RAM124.HTM].

[135] AEP has a rather extensive program in several states, particularly in Ohio. For more details see [http://www.aep.com/whatsnew/apetree.html].

[136] More detailed information and an application form for assistance may be obtained from:[http://www.pski.com/kdf/fsp.html].

[137] Ibid., [http://www.pski.com/kdf/fsp.html]

The status of forest conservation in Kentucky has recently been reviewed by Duane Bistow who, like all who take the effort the make a serious study of the topic, notes the need for a concerted effort on the part of the government and the public.[138] The Division of Forestry brings focus to this effort, as does legislation enacted during the 1998 session of the General Assembly (Kentucky Forest Conservation Act).

7.4   Policy Options for Enhancement of Carbon Sequestration

It is probable that many who read this document and associated literature will, after a few minutes of thought, ask a simple question. "Why do we need policy options to make trees and grasses grow? They will do it anyway."   This is an entirely reasonable question, and it is based on a premise that is absolutely correct. It is the nature of living systems, in this case plant life of all sorts, to reproduce and replace the fallen at every opportunity. Indeed, the spreadsheet developed for the Phase II study takes this into account in determining net emissions by applying the sequestration rate found for 1990 as a constant through 2020 (see Section 3.4.24).

The analysis developed in Chapter 7 suggests an increase in carbon sequestion in 2020 to 55,358,097 tons CO_2 per year for rural forest. In addition, policy initiatives to encourage forestation on urban-built lands might provide another 2,728,879 tons per year for a total of 58,086,976. The difference between this figure and the rate determined for 1990 is 58,086,976-38,211,999 = 19,874,977 tons per year. It is believed that this difference will in part (mostly due to rural forest) develop naturally. However, the difference can be enhanced through encouragement of sequestration policies and, if so, such enhancements can and should be accounted for in terms of emission reductions in the year 2020.

7.4.1 Policy options for enhancement of urban forest

Urban forest and community forest are not as well understood in terms of ecosystem relationships, and in terms of the relationship between an urban populace and

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[138] Bristow, Duane; *Forest Conservation in Kentucky;*[http://www.webcom.com/duane/wood/state.html] last revised November 12, 1996. This is a very readible text containing details from forest surveys 1975 and 1988. A brief history is also provided based largely on the work by Paul Camplin entitiled "*Forestry in Kentucky*" which was published in 1966.

its associated forest. One option for government policy makers that could benefit all in the future would be to fund research in this area. Based on better information and understanding, it is conceivable that a modest program of research followed by judicious programs for tree planting, and for the care of existing forest, could easily result in 10 percent of the projection for urban forest potential (Section 7.1) being obtained for a reduction of 272,888 tons of CO_2 per year by the year 2020. The programs would be in support of the existing Urban Forestry Assistance Program offered by the Kentucky Division of Forestry.[139]

Efforts armed with an extensive database derived from funded research, and empowered through expanded staff in the Division of Forestry, could undertake more aggresive projects for street tree surveys, park forest land tree surveys and urban tree planting and maintenance programs. A more aggressive program, if extended to all sectors and possibilities for urban and community forest systems, could result in all of the potential for urban forest being developed. This would be equivalent to a reduction in CO_2 emissions of 2,728,879 tons per year by the 2020.

7.4.2 Policy options for enhancement of rural forest

Opportunities for enhancement of carbon sequestration in the rural setting are far more extensive than for urban-built lands. Here, however, the circumstance is complicated by a diversity in forest land ownership. Extensive urban-community forest systems are found in parks and along roadways and streets. These can be managed through the government agency responsible to the immediate community. Privately owned trees in the urban setting are also a significant source. These cannot be managed in the sense of a park land forest, but they can be improved through assistance and information programs such as available through the Division of Forestry. The State's rural forests, however, present a somewhat different problem. Here, as noted previously, ownership is divided among 400,000 entities with only a small percentage being managed by government agencies.

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[139] Contact Kentucky Division of Forestry , 627 Comanche Trail, Frankfort, KY 40601, (502) 564-4496 for additional information concerning this assistance program.

A modest program going just beyond the current Forest Stewardship Program and Division of Forestry reforestation programs could reasonably be expected to provide at least 5 percent of the benefits projected above, for a reduction in emissions equivalent to 2,767,905 tons per year. A more aggressive program supported first by funded research seeking accurate and current tree and harvest statistics for the State could achieve far more. It is conceivable that such a program coupled with: expanded staff and budgets in the Division of Forestry; selective return and management of crop and pasture land to forest; regulation of timber harvest practices insuring protection of soil carbon and enhancement of new growth; and extension of RAM 124 techniques to all potential mining sites could easily reduce CO_2 emissions by the full amount projected for 2020 if put in place by 2000. This would be equivalent to 55,358,097 tons CO_2 per year. Assuming that a reduction of 38,211,999 tons per year would take place anyway (1990 baseline), and then further assuming the State will only be given credit for the difference due to new policies in place and enforced as of 2000, still leaves 17,146,098 tons CO_2 per year to be counted toward reductions.

7.5 Summary of Carbon Sequestration Issues

The issues surrounding carbon sequestration have been given a fairly complete review in Chapter 7. It was anticipated at the outset of the study, given that fully 50 percent of the Commonwealth is covered by forest, and that these forest were fueling a $3 billion per year timber industry, that this would be an important issue. What is offered are initiatives designed to take advantage of the huge benefit offered by the extent Kentucky forest which.

It is proposed that the EQC launch a "common sense initiative" directed toward the maximization of carbon sequestration on Kentucky lands. A diverse committee of experts and stakeholders would develop recommendations for the following activities: management of crop and pasture land returning to forest; management of privately-owned timberland, including harvesting methods; and management of the urban forest. It seems appropriate to bring this all into some focus. The benefits of such an initiative to the Commonwealth and its citizen would be enormous.

The General Assembly of the Commonwealth of Kentucky enacted legislation

in 1998 designed to ensure the future of Kentucky's forest. The legislation is entitled the Kentucky Forest Conservation Act. The Act promotes long-term timber production, detailed resource surveys, economic development of forest resources and, in general, promotes the continuance of healthy, high-quality forest. The Act dose not list enhancement of carbon sequestration as a specific goal, but many features of this important land-mark legislation do contribute to sequestration none-the-less.

8. SUMMARY AND DISCUSSION

The strategies described in Chapters 6 and 7 are summarized in Table 13 on the following page along with their attendant reductions of greenhouse gas emissions. Emission reductions for the set of modest policy options totals 13,188,142 tons of CO_2 per year in the year 2020. Subtraction of this figure from the baseline emissions for 2020 of 256,728,755 gives 243,640,613 tons per year for 2020, which is 19 percent above the inventory value for 1990 of 205,520,311 tons per year determined in Phase I of the study.

The maximum effort policy initiatives would result in reductions of 51,776,830 tons of CO_2 per year in the year 2020. Subtraction of this figure from the baseline emissions for 2020 gives 204,951,918 tons per year for 2020, which is essentially the same as the 1990 inventory value. For all intents and purposes, it can be stated that the maximum effort initiatives do indeed meet a goal of holding 2020 emissions to 1990 levels.[140]

A discussion of some of the major issues concerning the proposed mitigation strategies follows the summary Table 13.

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[140] Phase I and II studies required extensive spreadsheet calculations. The only way to keep track of these calculations, and to confirm when necessary just exactly how a calculation was made, was to keep and print the numbers as generated. In practice none are more accurate than just a few significant digits and should be rounded accordingly.

Table 13. Summary Table: Strategies for Reducing Greenhouse Gases for the Commonwealth of Kentucky for the Period 2000 through 2020

Sector	Policy Options to Reduce Greenhouse Gas Emissions	Modest Options (tons CO_2 per year)	Max. Effort Options (tons CO_2 per year)
Residential	Enforcement of building codes	231,255	952,022
	Home Energy Rating System (HERS)	66,909	509,378
	Solar heating for low temp. applications	28,984	130,119
	Solar electric systems	11,538	82,085
Commercial	Enforcement of building codes	583,074	2,332,296
	Energy efficiency in government buildings	94,227	456,336
	Solar heating for low temp. applications	21,805	94,227
	Solar electric systems	9,176	58,460
Industrial	Expanded IAC/KPPC programs	113,288	5,531,419
	Solar heating for low temp. applications	77,403	372,214
	Recovery of HFC-23 byproduct	3,131,004	6,258,309
	Coal-bed methane recovery	23,349	200,194
	Landfill gas recovery	720,000	1,440,000
Transportation	Feebates for fuel efficient vehicles	1,244,404	2,392,272
Utilities	Shift coal to gas (NGCC/IGCC/AFT)	3,652,701	10,950,702
Agriculture	Manure management	38,232	141,827
Carbon seq.	Urban forest management programs	272,888	2,728,879
	Rural forest management programs	2,767,905	17,146,098
Totals	Totals reductions due to for policy options	13,188,142	51,776,830
	2020 Baseline corrected for reductions	243,640,613	204,951,918
	2020 Baseline minus base sequestration	205,440,613	166,751,918

8.1 Re-Powering (Fuel Switching) Initiatives for the Utility Industry

The "re-powering" initiative described in Chapter 6 calls for the construction of seven to eight 400 MW facilities over the period 2000 to 2020. By any description, this would be considered a major undertaking. The planning and design of such a project, in whole or in part, is well beyond the scope of this study, although recognition of the need for this effort does originate here. It is suggested that, if this initiative is considered viable, a group be formed of experts and interested parties to undertake a feasibility study. Many choices and decisions will need to be made in the process of achieving this goal.

One feature of the initiative proposed above should not be overlooked. It is true that the proposal does call for replacement of a substantial portion of the utility coal-base with a gaseous clean burning fuel. It is also true, however, that the initiative leaves open the possibility of keeping coal in the fuel feed line <u>at its original level</u> through IGCC and AFT/IGCC systems.

8.2 Implications of the Kyoto agreements

The United States was a recent participant in the conference in Kyoto, Japan where, after lengthy debate, it was agreed that the U. S. would try to bring its emissions down to seven (7) percent below 1990 emissions levels by the year 2012. The agreement is not binding but does provide us with a useful tool for evaluation of various mitigating strategies. The emission rate determined for the Commonwealth from its 1990 database was 205,520,310 equivalent tons of CO_2 per year.[141] Reductions to seven (7) percent below this figure by 2012 require that the state bring emissions down to 191,000,000 equivalent tons of CO_2 by that date. Base case projections for 2012 derived from the policy analysis spreadsheet discussed in Chapter 3 give an emission rate of 243,540,673

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[141] Spencer, Hugh T., *Kentucky Greenhouse Gas Inventory: Estimated Emissions and Sinks for the Year 1990,* The Kentucky Natural Resources and Environmental Protection Cabinet, Division of Energy and the KIESD, Center for Environmental Engineering, University of Louisville, with funds from US EPA Office of Policy, Planning and Evaluation, Federal Assistance No. CX822849-01-0, p. 9, 1996.

tons CO_2 per year, a figure in excess of the 191,000,000 target by 53,000,000 tons CO_2 per year.

An analysis conducted with the policy analysis spreadsheet developed for the Phase II study suggests that Kyoto agreement figures can be met in Kentucky, but only when initiatives that go well beyond the maximum effort policy options outlined in Chapter 6 are applied. Energy end-use efficiency measures and transportation fuel efficiencies 3 to 4 fold beyond the maximum effort would have to be applied. In addition, it would prove necessary to re-power at least 60 percent of the utility coal-base with natural gas or gasified coals to be used in IGCC and AFT systems. Thus, it does appear that the undertaking would prove difficult to accomplish. In addition, it should be noted that the General Assembly of the Commonwealth of Kentucky has passed on legislation that specifically prohibits the promulgation of regulations pursuant to the Kyoto agreements.[142]

8.3 Economic considerations

Further evaluation of the economics of the suggested policy options is probably not a realistic possibility for this study. Complex macroeconomics economic models are currently being applied to resolve a number of economic issues but some those most frequently employed are not designed to evaluate GHG mitigation policies. The REMI-EDFS model, for example, is a popular regional macroeconomic model used to assess the impacts that shifts in demography, local initiatives and external events may have on local economies. The REMI-EDFS model could be of benefit if provided for a given policy initiative with direct costs, costs of benefits and other external costs. The model is expensive ($46,000 to purchase and $12,500 to rent for three months) and generally requires an economist with experience in modeling to be the operator.[143] Some smaller less expensive models are also available (IMPLAN at $2,000 to $3,000 for a state database), but these also lack the ability to evaluate GHG mitigation strategies directly. IMPLAN also suffers in its inability to account for changes in relative prices of goods,

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[142] SB 300 entered February 12, 1998 creating a new section of subchapter 20 of KRS Chapter 224.
[143] *Summary Review of Models for Analyzing and Reducing Greenhouse Gas Emissions at the State Level,* Prepared for US EPA State/Local Climate Change Program by the ICF Consulting Group, September 8, 1997, p. 20.

time shifts and supply constraints, features critical for analyzing energy related phenomena. For these reasons, and given the budget constraints for the Kentucky Phase II project, it was decided to approach the economic analysis for various mitigation strategies on the basis of routine engineering design economics, although this as well proved difficult. Consider, for example, the cost-to-benefit ratio for placing 1,000 acres of cropland in a carbon sequestration "bank." The costs for re-seeding the land with productive hardwood stock will run $200 to $300 per acre. Taking $250 as the average gives $250,000 as the need for initial capital. In addition, there is also the cost of taking this land out of production for crops for a forty-year period, assuming that we intend to harvest the wood stand at that time. It is at this point that the analysis begins to become difficult. If, for example, we propose to take 1,000 acres of productive tobacco land out of service we have to deal with a loss in the first year of $2,200 net return per acre, or of a sum $2,200,000 for the total of 1000 acres. This is not a small sum, and it is for only one year. On the other hand, if we take 1,000 acres of corn crop out of production, the loss in the first year will be only $120 net per acre, or $120,000 total. The net present worth of the losses due to lack of crop production would, of course, developed over a forty-year period would be much, much greater. Indeed, it is difficult to believe that return on the initial investment could possibly equal such a sum.

The return of less productive land to forest, or of tobacco land if that crop ceases to be grown in quantity in Kentucky, is a different story. Cubbage *et. al.* suggest that the net present value of land returned to forest can be as high as $1,563 per acre for landowners who receive assistance in planning and re-seeding at the outset.[144] This then suggests that lands with minimal agricultural value can be productively cultivated for forest so long as the long time frame for return is acceptable.

The secondary economic benefits that come with the 1,000-acre "carbon bank" must also be considered, but here the accounting becomes more speculative. It is anticipated that our carbon bank will preserve jobs in the coal industry if utilized to offset

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[144] See Cubbage, F. W., Public and Private Forest Policies to Increase Forest Area Timber Growth: Programs, Accompolishments, and Efficiency, as printed in *Forest and Global Change, Volume 2: Forest Management Opportunities for Mitigating Carbon Emissions* by R. N. Sampson and Dwight Hair, American Forest, P.O. Box 2000, Washington, DC, 20013, ISBN 0-935050-05-1, p. 147, 1996. The data cited by Cubbage in this article comes from work done from 1983 through 1987.

demands for reduction in coal production due to future emissions restrictions, and that it will be of benefit to economic development in other sectors of the Kentucky economy as well. The questions that need answers are "Which sectors?" and "How much?"; and, if we are to believe that global climate change is due in some part to human activity, we must also determine the benefit derived from our 1,000 acres for ameliorating the impact---truly an impossible figure to develop, but quite possibly the most important in the long run.

It appears probable that the economic benefits derived from a carbon sequestration program, from conversion of coal resources to marketable clean burning gases, and from energy efficiency will never be known exactly. However, it is also apparent that application of a proper selection from the policy options offered will at the least do two things: (1) the Commonwealth will likely be in compliance with any future and binding international agreements to reduce greenhouse gases and, as a result, (2) Kentucky's industries, businesses and government will by that time be well on the way to becoming some of the most competitive and cost effective in the world. These goals, however, cannot be achieved without effort. It is possible that some industries, particularly those closely associated with coal production and coal mining operations themselves, may for a time be subjected to severe economic regional decline as a result of constraints driven by climate change. These same industries, however, could also derive enormous benefits from research and designs directed toward developing clean coal technologies. If so, these industries too will in time be found among the more productive and competitive.

9. REPORT APPENDICES

9.1 Glossary of Terms and Abbreviations

9.2 Policy Initiatives Worksheet

9.3 Urban Forest Development Worksheet

9.1 Glossary of terms and abbreviations

AFT— **A**dvanced **F**uel **T**echnology. This term appears in association with AFT-IGCC coal-waste to clean gas conversion systems. In its regular use it applies to AFT briquettes.

CAA — **C**lean **A**ir **A**ct. CAA is used herein to represent the CAA as amended in 1990. The Clean Air Act was enacted in 1970 and subsequently modified in 1977.

IGCC— **I**ntegrated **G**asification **C**ombined **C**ycle. This term finds application in General Electric's literature describing the GE - IGCC system, usually in association with coal gasification and a GE gas turbine. In the case of AFT-IGCC systems the gas comes from gasification of a coal-waste mixture. The waste stream can come from either industrial or domestic supply, provided it is combustible, or from sewage sludge.

NCAQ — **N**ational **C**ommission on **A**ir **Q**uality. The CAA Amendments of 1977 empowered Congress to establish a commission to make an independent analysis pollution control and alternate strategies for achieving the goals of the Act. The commission had thirteen members and was charged with the collection and evaluation of information relating to environmental, technological, social and scientific issues pertinent to air quality policy.

PSD — **P**revent **S**ignificant **D**eterioration. PSD areas were established through the 1977 Amendments for the sake of preventing deterioration of air quality in areas that, at the time of the enactment, were already cleaner than required by national air quality standards.

OTAG — **O**zone **T**ransport **A**ssessment **G**roup. The Environmental Council of the States along with US EPA formed this group from the environmental agencies from the thirty-seven easternmost states.

OTC — **O**zone **T**ransport **C**ommission. The group established to manage the OTR. It consists of twelve state governors or their designees, and a representative from Washington, DC.

OTR — **O**zone **T**ransport **R**egion. The OTR was established by Congress through the 1990 Clean Air Act Amendments. It consists of the eleven northeastern states plus parts of Virginia, and the District of Columbia.

9.2 Policy Initiatives Worksheet

The "Policy Initiatives Worksheet" is a complex Excel 7.0© spreadsheet derived from the US EPA Workbook employed in developing the 1990 inventory for Kentucky. The original 1990 Inventory spreadsheet was constructed on a county basis, as is the Policy Initiatives spreadsheet shown below. Collectively, these various Excel© spreadsheets hold some 30,000 data items and line operations. The worksheet shown is for Policy Set V, Table 13. It is one of many possible examples.

Column A provides information for adjoining cells in Column B. Column C provides information for adjoining cells in Columns D, E and F. A summary of these informational statements is given below according to cell citation.

For Columns A and B:

A1. The year of projection shown in this example is 2010.

A2. The number of years projected is 20 counting from 1990.

A4. The gross emissions projected for 2010 given the specifications listed in Columns C, D, E and F.

A5. The net carbon sequestration for urban and timberland recovery counting from January 1, 2000 through December 31, 2010.

A6. (The study year - 1999) ÷ 10. This term is used to assess the fraction of sequestration benefit to be applied from January 1, 2000 to December 31 of the target year.

A7. Net emissions rate at the end of the study year assuming the policy initiatives listed in Column C take effect January 1, 2000.

A9. The target emissions rate is the 1990 inventory figure less 7 percent as per the Kyoto proposal. We are to be at this rate by the end of the year 2012.

A12. The deficit between the 2010 emissions rate and the Kyoto proposal. This is the deficit present with two years of corrective action to go.

A16. The policy initiatives spread sheet was originally written for the period 1990 to the study or projected year. It was changed during the course of the study to have policy initiative effects apply beginning on January 1, 2000. This requires that the benefits calculated for the period 1990 to December 31, 1999 be subtracted away. The correction for this particular set of initiatives is shown in cell B16.

A17-A25. These cells contain reminders advising the user how to proceed in developing the correction applied through cell B16.

For columns C, D and E:

Column C provides the policy initiative in verbal form, Column D gives this information as a percentage of improvement. The figures in Column D for the Base Case are discussed at length in Chapter 3. Column E provides a multiplier for the percentages listed in Column D. Any of thousands of combinations of initiatives can be tried here be simply changing the figures in Column D. For example, in the set shown, the multiplier for "Increase in efficiency for residential use" is 5. This has the effect of multiplying the figure in cell D3 (10 percent) by 5 to give a 50 percent improvement by the end of 2010. The 50 percent figure is shown in cell F3.

	A	B	C	D	E	F
1	study year	2010		base	policy	2020%
2	years projected	20		2020%	mult.	
3			Increase in efficiency for residential fuel use	10	5	50
4	emissions T CO2/yr.	222,419,351	Emissions per unit of transportation fuel drop by	10	5	50
5	net carbon seq. delta	16,863,893	Efficiency in transportation fuel use increases by	10	5	50
6	seq. delta mult.	1.1	Increase in efficiency for commercial fuel use	10	5	50
7	net rate tons/yr	203,869,068	Increase in efficiency for industrial fuel use	10	5	50
8			Annual increase in gross domestic product (%)	1.5	1	
9	target	191,133,888	Increase in gross domestic product by 2020	45.00	NA	45
10			Increase in efficiency for residential electricity use	10	5	50
11			Increase in efficiency for commercial electricity use	10	5	50
12	deficit	12,735,180	Increase in efficiency for industrial electricity use	10	5	50
13			Annual increase in electricity demand (%)	1.4	1	
14			Increase in elec. without baseline reductions (%)	42.00	NA	
15			Increase in elec. with baseline reductions (%)	29.75	NA	29.75
16	rem: correction in S28	38,810,431	Reduction in direct coal-fired elec. BTU	50		
17	must be frozen at its		Portion shifted to natural gas-coal gas conversion	90		
18	1999 value.		Portion shifted to wind	0		
19			Portion shifted to solar	0		
20	Type =S28 in cell B16		Portion shifted to oil	10		
21	with year = 1999 and					
22	with test data set.		Resultant elec. BTU split for 2020 AD:			
23	Freeze this value.		natural gas-coal gas conversion	44.95		
24	Then proceed through		oil	5.41		
25	the years 2000 to 2010.		hydro	0.24		
26			coal	49.67		
27			solar	0		
28			wind	0		
29						
30			Increase in biomass use for power and heat	10	1	10
31			Drop in cfc/hcfc losses	20	4	80
32			Drop hcfc-22 by-product losses	20	5	100
33			Annual increase in coal production	0.5	1	

34			Increase in coal production (%)	15	NA	15
35			Drop in emissions due to methane capture	5	1	5
36			Drop in emissions due to fertilizer	10	1	10
37			Drop in emissions due to landfills	10	5	50
39			Drop in emissions due to sewer systems	10	1	10
40			Drop in emissions due to manure management	10	1	10

9.3 Urban Forest Development Worksheet

The article "Construction of a National Urban Forest Model" by Sampson and Kielbaso as it appeared (Appendix 5) in *Forest and Global Change: Volume I Opportunities for Increasing Forest Cover*; an American Forest Publication, P. O. Box 2000, Washington, DC 20013 was re-typed for presentation herein without change or alteration. The spreadsheet which follows is from the adaptation of this model to Kentucky with a projection time frame extending out to 2010.

Construction of a National Urban Forest Impact Model

by R. Neil Sampson and J. James Kielbaso

We have developed a simple spreadsheet model to assist in the calculation and display of the benefits that Urban and community forests bring in terms of energy conservation and carbon sequestration. In so doing, we have leaned heavily on data that are often very thin and made assumptions that need to be refined by further research. The advantages of the model, however, are that we can enter a new data and new assumptions rather easily and get immediate changes that help us determine how sensitive the model is to each input.

The following pages reproduce the model and provide extensive notes that should help reviewers follow the assumptions and logic that were utilized in the process. At this stage, it is important to treat this model as a working tool and not as a reliable predictive calculator. As such, it fits into the family of working tools being developed to calculate and illustrate the opportunities for improving trees and forests in the United States as one of the strategies for addressing the global climate change issue. Since a great deal of work and improvement are occurring in each of the technical areas involved, it will be important to continue research efforts on urban and community forests in order that this area of knowledge grow and improve rapidly enough to keep up with improvements in other aspects of forestry and energy conservation.

Notes to the Model

1. The percent of urban land in four general land-use categories is taken as an average of several research reports dating from the 1960's to the present. See, for example, Goodman and Freund (1968), Murphy (1966), Rowntree (1984), and Talarchek et al. (1985). Where these urban land-use studies included significant amounts of agricultural and vacant land within the urban area, that land was removed from the calculation and the percentages reported were adjusted accordingly because it is felt that agricultural and vacant land parcels larger than 10 acres, even when they are

contained within an urban area, would not be included in the urban and builtup classification reported by the Soil Conservation Service.

2. The total urban and builtup land base against which these percentages are applied is the 50.3 million acres estimated to exist in 1987 (U.S. Department of Agriculture, Soil Conservation Service 1990 Unpubl.).

3. Percentages of available growing space were calculated by averaging the data developed in Syracuse, NY; Dayton, OH; Cincinnati, OH; and Birmingham, AL, by Rowntree(1984) and in New Orleans by Talarchek et al. (1985).

4-5. Based on the available growing space estimates calculated as indicated in note 3, and the acres of land in each use, one can derive the estimate that about half of the available growing space in America's urban areas exists in residential areas, with over
another one-quarter associated with the transportation system.

6. Current canopy cover estimates are developed from Rowntree (1984) and Talarchek et al. (1985) and represent the percentage of the available growing space occupied by canopy.

7. Canopy cover potential for the various land-uses is estimated by the authors as a realistic goal for improving urban and community forests.

8. Trees per acre of available growing space are estimated from the canopy cover data and are based on our assumption that 100 percent canopy cover would be reached with a tree population of roughly 100 per acre. Existing residential areas include the oldest and most well-established areas in communities, so the estimated number of trees per acre is slightly less than the estimated percentage of canopy cover, to reflect the existence of the older, larger trees.

9. Potential trees per acre of available growing space reflect the percentage of canopy cover sought, recognizing that these will be newly planted trees, in somewhat closer spacing than exists in some of the old, well-established areas.

10-14. Current trees, potential trees, percent increase, planting needs and planting per year

for a 10 year program to fill the planting potential are calculated directly from the acreage estimate and the estimates of trees per acre of available growing space.

15. Replacement plantings are the number of trees that would be required if average tree life were 50 years (an optimistic estimate, given current surveys) and trees were replaced promptly when they died (another optimistic scenario, in most communities today). We feel that this is not an unrealistic goal, however.

16. Tons of biomass per tree are estimated from Wenger (1984) and Smith (1985). An average green aboveground biomass for nine hardwood species in West Virginia is given in Wenger (table 48). Conversion factors from green to dry weight for these species are contained in Smith's paper. The aboveground dry weights were increased by 20 percent to account for stump and root weights. Average dry biomass weight for the 9 species was divided by 2 to get average carbon weight. For a tree 12 inches in diameter at breast height, the calculation resulted in an average of 684 lb of dry carbon per tree.

17-18. Tons of soil carbon per treed acre and per grassed acre are taken from Birdsey's estimates, and Persons' work on Forest Service data for the Southeast. These data need further research and refinement before they can be assumed to represent national conditions, but they appear to be the best currently available.

19-27. The current and potential situation calculations come from the factors contained above. For example, carbon storage contained in trees within residential areas (line 19, first data column) was obtained by multiplying 407 million trees times 0.35 tons

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carbon per tree. It should be noted that in this calculation, the total tons were divided

by 1 million to give million-ton estimates that compare to the national carbon-emission

estimates. Rounding these calculations to the nearest million tons probably still

over reflects the degree of certainty involved in the basic data.

28. National carbon emissions from the various land-uses were estimated by taking the
percentage contributions for each land-use category estimated by DiCicco et al.
(1990) and adjusting them for the total national estimate provided by Boden et al.
(1990).

29. The added annual storage potential of urban trees and urban soils was calculated as 2
percent of the increased storage achieved by planting the new trees to reach the
potential estimated for the different land-uses, at the current acreage levels.

30. The annual carbon emission reductions for air conditioning in residential areas was
calculated by estimating that 9 percent of the carbon emissions in those areas is the
result of air conditioning (DeCicco et al 1990) and that the potential savings as a
result of improved tree cover could be 15 percent (Akbari et al. In press). For
commerce and industry, air conditioning was estimated to generate 5 percent of total
emissions and be susceptible to a 10 percent savings due to tree improvement.

31. The annual carbon emission reductions for heating were calculated by estimating that
37 percent of the total emissions are the result of space heating (DeCicco et al. 1990)
and that savings from trees could be 10 percent on average. For commerce and
industry, it was estimated that space heating produced 10 percent of emissions and
that a 5 percent saving was possible.

32. Estimates for "other" savings were calculated as follows: Residential - 39 percent of
total emissions involved, a potential savings of 1 percent is feasible;
Commerce/Industry - 10 percent of emissions involved, potential savings 1 percent:

Transportation - 73 percent of emissions involved (autos and trucks), potential savings 1 percent; Public Facilities - 10 percent of total emissions for all land-uses, 1 percent savings possible. These savings should be realized through reduction of the urban heat island and associated pollution reduction.

33. The annual savings estimate as a percent of the annual emission estimate is calculated.

34-37. These calculations assume that the rate of urban and builtup development documented for 1982-087 by the Soil Conservation Service's National Resources Inventories continues for the next 20 years, that the currently estimated percentage breakdown of urban land-uses continues unchanged, and that the available growing space within the various land-use categories in the future is the same as what we have estimated for the present. All of these assumptions are subject to challenge:
economic
pressures could change any of them and the estimates of current situations need to be firmed up by better research.

38. The tree-planting need per year would be the amount of trees needed to plant an average of 1 tree per acre on the available growing space for each percent of canopy cover that is sought. A portion of this tree-planting need can be met by tree preservation because where a health tree can be retained during the development process, not only is the tree space filled but it is filled with a larger, better established, and more immediately beneficial specimen. It is only fair to note, however much we would like to see trees saved during development, that getting the "right tree in the right place' is not always possible on the basis of what already exists, even with the most skillful urban designs. There are many times when removing the existing trees and replacing them with the right species in the right location will provide the most benefits over the life of both the trees and the development.

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39. Carbon sequestration was calculated as an average sequestration rate per tree of 13 lb per year, and converting it to millions of tons per year 2010 by multiplying the number of trees planted per year times 20 years (for the cumulative effect of 20 years of tree planting that should be growing by 2010), and dividing by 2,000 and 1,000,000 to convert from pounds per year to million tons per year.

40. Energy conservation impacts of trees in new developments were calculated as occurring in the same ratio to carbon sequestration as had been computed for current forest impacts in the land-use. For Residential, that means calculating the ratio between the saving s(notes 31-33) and the sequestration (note 29). That comes out to a ratio of about 3.5 when averaged across all land-uses.

41. The total is the sum of 39 and 40.

42-43. These add the totals form existing acreage (between 32 and 33) to the totals for properly afforesting new development (39-41) to get an estimate of the annual benefit stream that might be realized after 20 years of a continued effort to improve urban and
community forests. No attempt was made to express the potential 2010 carbon impacts in terms of their percentage impact upon national output, because there was no basis upon which to evaluate the potential U.S. output levels by 2010.

44. No attempt was made to express the potential 2010 carbon impacts in terms of their percentage impact upon national output because there was no basis upon which to evaluate the potential U.S. output levels by 2010.

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	Footnote	Resident.	Com/Ind.	Transport.	Public fac.	Totals
	Estimate of built-urban acres					1,000,000
	Current land use and forest condition					
1	Percent urban land	45	14	30	11	100
2	Estimated acres (1987)	450,000	140,000	300,000	110,000	1,000,000
3	Avail. growing space(AGS)%	45	25	40	80	44
4	AGS (acres)	202,500	35,000	120,000	88,000	440,000
5	Land use as % of AGS	46	8	27	20	100
	Forest improvement potential					
6	Canopy-Current (%)	50	22	10	45	
7	Canopy-Potential(%)	60	30	30	50	
8	Trees/AGS Acre-Current	40	20	10	30	
9	Trees/AGS Acre-Potential	60	30	30	50	
	Existing urban acreage					
10	Trees-Current	8,100,000	700,000	1,200,000	2,640,000	12,640,000
11	Trees-Potential	12,150,000	1,050,000	3,600,000	4,400,000	21,200,000
12	Increase-Percent	50	50	200	67	68
13	Planting needs	4,050,000	350,000	2,400,000	1,760,000	8,560,000
14	Planting/year (10 years)	405,000	35,000	240,000	176,000	856,000
15	Replacement plants/yr (1/50)	347,143	30,000	102,857	125,714	605,714
	Carbon sequestration estimates					
16	Tons carbon/tree	0.35	0.35	0.35	0.35	
17	Tons soil C/AGS treed acre	20	20	20	20	
18	Tons soil C/AGS grass acre	10	10	10	10	
	Current situation-existing acreage					
19	Current situation-existing acreage	2.835	0.245	0.42	0.924	4.424
20	Soils-treed (M/Ton)	2.025	0.154	0.24	0.792	3.211
21	Soils-grassed (M/Ton)	1.0125	0.273	1.08	0.484	2.8495
	Total carbon storage	5.8725	0.672	1.74	2.2	10.4845
	Potential situation-existing acreage					
22	Carbon storage-trees (M/Ton)	4.2525	0.3675	1.26	1.54	7.42
23	Soils-treed (M/Ton)	2.43	0.21	0.72	0.88	4.24
24	Soils-grassed (M/Ton)	0.81	0.245	0.84	0.44	2.335
25	Total carbon storage	7.4925	0.8225	2.82	2.86	13.995
26	Increased storage (M/Ton)	1.62	0.1505	1.08	0.66	3.5105
27	Increased storage %	27.5862	22.3958	62.069	30	33.4828
	Current carbon pollution estimates					

28	Carbon emission (M/Tons/yr)	1.6364	26.4545	8.1818	0.7255	36.998
	Estimated impacts-existing acreage					
29	Added C storage potential/yr.	0.0324	0.003	0.0216	0.0132	0.0702
	Energy savings potential (M/Tons/Year)					
30	Air conditioning	0.0221	0.1323			0.1544
31	Heating	0.0605	0.1323			0.1928
32	Other	0.0064	0.0265	0.0597	0.037	0.1296
	Total savings potential	0.089	0.291	0.0597	0.037	0.4767
	Total carbon offset/year	0.1214	0.294	0.0813	0.0502	0.547
	Carbon reduction/year					
33	as % of national total	7.42	1.1114	0.994	6.9195	1.4783
	Potential impact-afforesting new development					
34	Annual development acreage	7,158	2,227	4,772	1,750	15,908
35	AGS%	45	25	40	80	44
36	AGS acres	3,221	557	1,909	1,400	6,999
37	Canopy cover (%)	60	30	30	50	
38	Tree planting need/year	193,277	16,703	57,267	69,993	337,241
	Annual impact by 2010-new development					
39	Carbon sequestration (M/T/Y)	0.0126	0.0011	0.0037	0.0045	0.0219
40	Energy conservation	0.044	0.0038	0.013	0.0159	0.0767
	Total carbon impact from complete reforestation of					
21	10 years growth	0.0565	0.0049	0.0168	0.0205	0.0986
	Total impacts-Planting existing area plus					
43	new developments per year by 2010	0.045	0.0041	0.0253	0.0177	0.0921
44	Energy conservation	0.133	0.2948	0.0728	0.0529	0.5535
	Total annual impact	0.178	0.2989	0.0981	0.0707	0.6456
	Total annual urban removal					
	as tons of CO2 per year	652,490	1,095,951	359,619	259,128	2,367,188